Journal of Materials and Environmental Sciences
ISSN: 2028-2508

JMES, 2017 Volume 8, Issue 7, Page 2372-2380

http://www.jmaterenvironsci.com /

ERVD4, 26-27 Oct 2016 Ifrane, Morocco

First step of waste chicken skin valorization by production of biodiesel in Morocco

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Received 29Aug 2016,
Revised 01Oct 2016,
Accepted 04 Oct 2016

Keywords

- ✓ Biodiesel,
- ✓ chicken skin,
- ✓ temperature,
- ✓ time,
- ✓ extracted-oil

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Abstract

The issue of raw materials is a critical point that affects the economic feasibility of biodiesel production, since they account for about 80% of the total cost of biofuels. Today edible vegetable oils are the main raw materials for the production of biodiesel. Recently, lipid residues such as used cooking oil and inedible fats have also received considerable attention in the biofuels sector. White meat currently contributes over 40% of total meat consumption in Morocco [1]; so this sector generates a significant amount of wastes. The extents of treatment are poorly developed and wastes are haphazardly deposited in landfills. That is why we chose chicken skin as a raw material in our biodiesel synthesis process. We have selected for this work focusing on the study of the variation of two variables (temperature, time) during the first step of biodiesel synthesis process in order to have the maximum of extracted oil that can be used later.

1. Introduction

Biodiesel is defined as "a fuel consisting of monoalkyl esters of long chain fatty acids derived from vegetable oils or animal fats" [2]. Biodiesel enter into the prospects for reducing greenhouse gas (GHG), established in the Kyoto Protocol [3], [4] for the development of mechanisms for the reduction of dioxin emissions, derived furan and for persistent organic pollutants or POPs originate from the combustion of petrodiesel.

The issue of raw materials is a critical point that affects the economic feasibility of biodiesel production, as they have about 80% of the total cost of biofuels. In this context, several efforts have been made to reduce the price of biodiesel, mainly by changing the lipid sources [5], [11]. After seeing the excess of chicken and pork skin/fat in the market, we realized that this waste could be used to create biodiesel. This biodiesel could be used to power automobiles (with modified engines), for domestic purposes and biodiesel could also be a cheaper source of fuel compared to refinery diesel [2].

In our project we tried to synthesis from animal fat while focusing on the skin of chickens since the waste at this level is a huge amount. The method of synthesis of biodiesel from the skin of chickens involves three main stages (**figure 1**): Cooking in which has been used a self-thermos, esterification and transesterification. The progress of each step depends on a number of parameters that need to be targeted through the development of a clear experimental design will allow us to have a better performance at the end of our process. The experimental design is the ordered sequence of trials of experimentation, each to acquire new knowledge by controlling one or more input parameters to obtain results validating a model with a good economy (number of trials the lowest possible, for example).

2. Experimental details

In this section we have determined all that can be necessary for the first step of synthesis of biodiesel from chicken skin as follows.

2.1. Raw materials and Solvent

The raw materials and solvent used in this step were: Chicken skin, Water, Chloroform.

2.2. Apparatus

The apparatus used in the first step were: Beakers of 600 ml; beakers of 1L, electronic balance accurate to 1g, 1 Scalpel, mounting of distillation (reflux condenser, Dean-Stark receiver 10 ml, triple-neck flask), mounting vacuum filtration (vacuum pump, Buchner funnel), 1 measuring cylinder of 10 ml, Magnetic stirrer with heating, Separating funnel of 500ml capacity, pressure cooker "aluminum alloy - useful volume 8 liters. With mano-thermometer dial, temp max + 127C, P max: 2 bar".

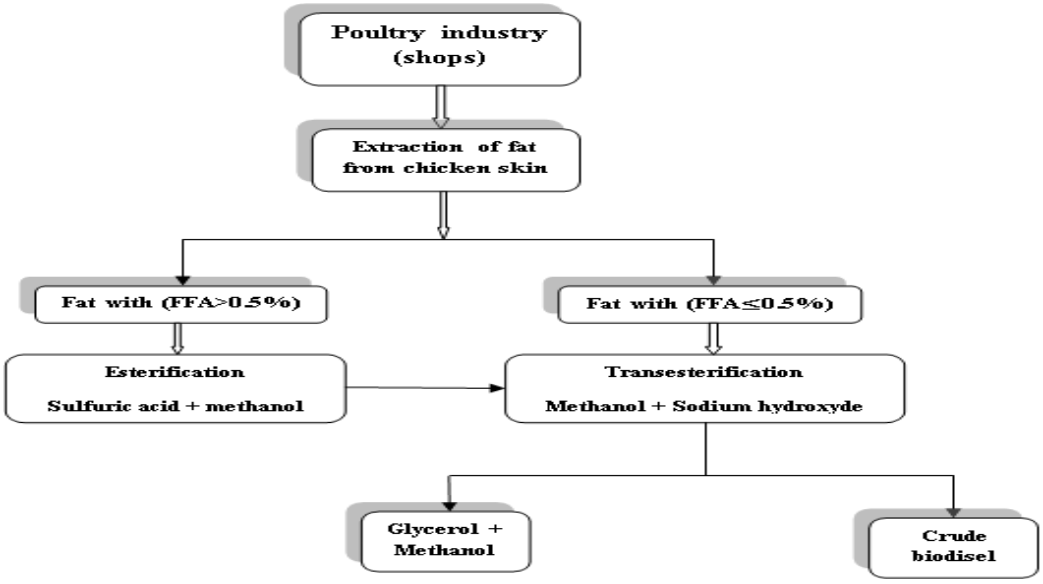

Figure 1: Schematic representation of the main steps to obtain biodiesel from chicken skin

2.3. Extraction of oil from chicken skin

Large quantities of animal discards are produced from the slaughtering and processing of livestock, and much of this waste biomass is animal fat. According to Adebanjo [12] about 27.9 million metric tonnes of animal fats are produced globally each year, and these animal discards can be used to produce biodiesel [13]. Oil crops such as soybean and canola can also be used for biodiesel production [14], but the use of edible crops for biofuel production is viewed as contributing to high food prices and accentuating the global food crisis [12]. The use of animal discards to produce biodiesel not only avoids the food-fuel dilemma, but reduces the problem of animal waste disposal and contributes to the global initiatives to increase the global supply of biofuels [15].

Oil was expelled from the feedstock (chicken skin) by appropriate means. First, 200 g of chicken skin waste was cut into small size by using a scalpel and heated in a pressure cooker at a temperature and for a time situated in the following range (110 ˚C, 120 ˚C) and (30min, 90min) [16]. A mass of oil is expelled from chicken skin after heating and separation of all parts. About 200 g of chicken skin was used in all experiences; it was thoroughly washed using tap water. It was then immersed in a beaker containing 1 liter of water. The content of the beaker was poured into a basket which was attached to the inside of a pressure cooker. The liquid portion obtained was separated into layers using chloroform ($CHCl_3$). The three layers were obtained: a solid layer and an aqueous layer containing triglycerides (or an organic layer / fat). The solid phase was separated from the aqueous phase and the organic phases with the basket of the pressure cooker and the aqueous phase (which in this case was white in color) was separated from the organic layer using a bulb decant. The organic layer was temporarily stored in a conical flask and the solid layer (or the solid mass) was carefully heated in about 400 ml of water. The formed mixture is further cooked in a pressure cooker to a quarter filled with water under pressure by pouring the mixture into a container. After a temperature and for a time that will be determined afterwards, the solid layer has been removed, and separated to get rid of any solid sediment (known as "massive"). The resulting liquid portion was separated in a separator funnel at an organic layer containing triglycerides and an aqueous layer. Chloroform was added to the aqueous phase to extract any remaining fat by using chloroform again. The extracted oil was stripped of any sediment or suspended matter by using vacuum filtration. When we have determined all variables in we can have a maximum extraction we are worked on a larger amount of the chicken skin in the following steps. When we finished our synthesis we have recuperated our solvent by using the mounting of distillation [17]. In the first part, the procedure to apply is the following (**figure 2**):

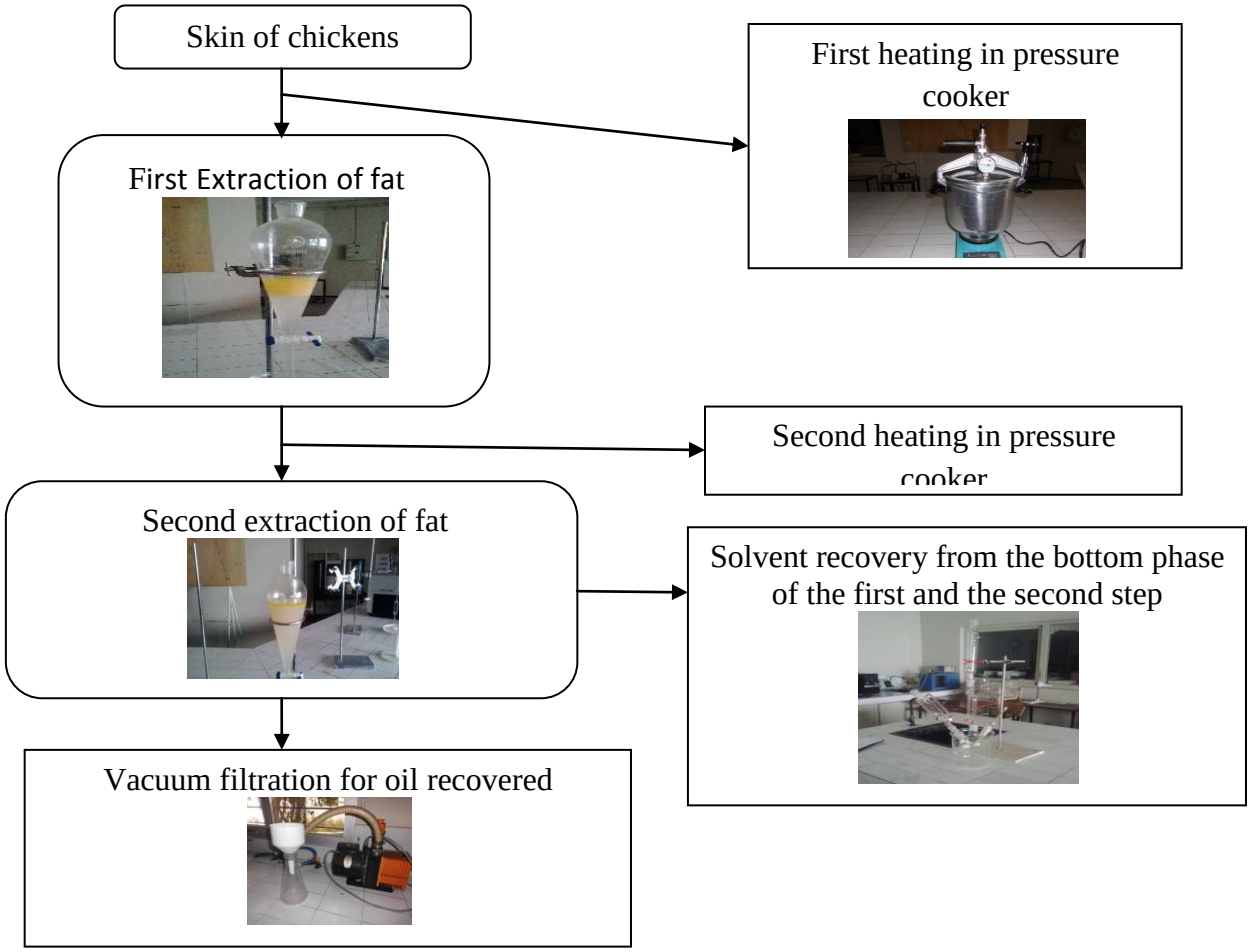

Figure 2: Diagram of the experimental method for extracting fat from skin of chicken

3. Results and discussions

3.1. Variables identification of the first extraction of oil from chicken skin

The first extraction will take place only in accordance with a set of variables, and those by making necessary tests. First, we modified the temperature and reaction time on a 200g of chicken skin sample for each stage whose purpose was to determine where the maximum is located. The main factors that influenced the quality of our extraction are: temperature and time (**table 1**).

Table 1: First reaction parameters values

Temperature (˚C)	Time (min)
110	30
120	90

3.2. Experimental design

We have two factors with two levels each. There are four possible combinations that can be made (**table 2**).

Table 2: Group of combinations for the different factors

Samples	Temperature (˚C)	Time (min)	Mass of oil extracted (g)	Volume of oil extracted (ml)
1	-	-	120	118
2	+	-	109	109
3	-	+	120	116
4	+	+	111	108
level -1	110	30		
level +1	120	90		

The "+" indicates the highest level (for example 120 degrees for temperature and 90 minutes for time). The "-" indicates lowest levels (30 minutes for the time) (**table 2**).

3.3. Analysis of variables influence

We will proceed to three analyses, effect of temperature, time and there interaction on our reply [mass (or volume) of oil (or fat) extracted] can be measured as follows:

- *Analysis of temperature effect*

We can conclude from the result, that temperature has an influence on the mass of extracted oil or grease, when the temperature increases the mass of extracted oil decreases. The percentage of the temperature influence is 8.7%.

- *Analysis of time effect*

We can conclude from the result, that time has no influence on the mass of extracted oil or grease in comparison with the influence of temperature, when the time increases the mass of extracted oil increases little. The percentage of the time influence is 0.87%.

- *Analysis of temperature and time effect*

The results obtained from the combination of the two factors are combined (**table 3**).

Table 3: Combination of factors with their interaction

Samples	A (°C)	B (min)	A*B	M(g)
1	110	30	+	**120**
2	120	30	-	**109**
3	110	90	-	**120**
4	120	90	+	**111**

With: A = Temprature; B = Time; M = masse of extracted oil

- *Analysis of the result of the combination A * B*

So we can conclude that the interaction between temperature and time almost didn't have influence as for the time. The mathematical model representing the first stage of experimental design is written in the form:

$$M(g) = a_0 + a_1 A + a_2 B + a_{12} AB$$

Where A and B are the temperature and time variables.

With: a_0, a_1, a_2, a_{12} are the polynomial coefficients. (a_0 =115; a_1 =5; a_2 =0.5; a_{12} =0.5)

Equation (4) of the polynomial model becomes.

$$M(g) = 115 - 5A + 0.5B + 0.5AB$$

3.4. Plotting curves of results

Treatment of experimental data was carried out under MINITAB software.

3.4.1. Pareto chart

When the tests are carried out and that we have all the answers, we can proceed to the mathematical or statistical analysis of the results.

Of all the factors studied, and the selected level of confidence (α = 0.05), temperature (A) appears as a very influential factor, time (B) and interaction (AB) do not have to significant effect on the response.

From this diagram (**figure 3**), we tried to reduce the reaction time at lower values than those with which we had worked at first since we had noticed that there was interaction between time and temperature in order to minimize energy consumption by reducing the reaction time (**table 4**).

3.4.2. Diagram of the main effects

The diagram of the main effects (**figure 4**) allows determining the influence of all the factors on the quantity of the oil extracted while representing the average of the masses extracted at both levels of factors.

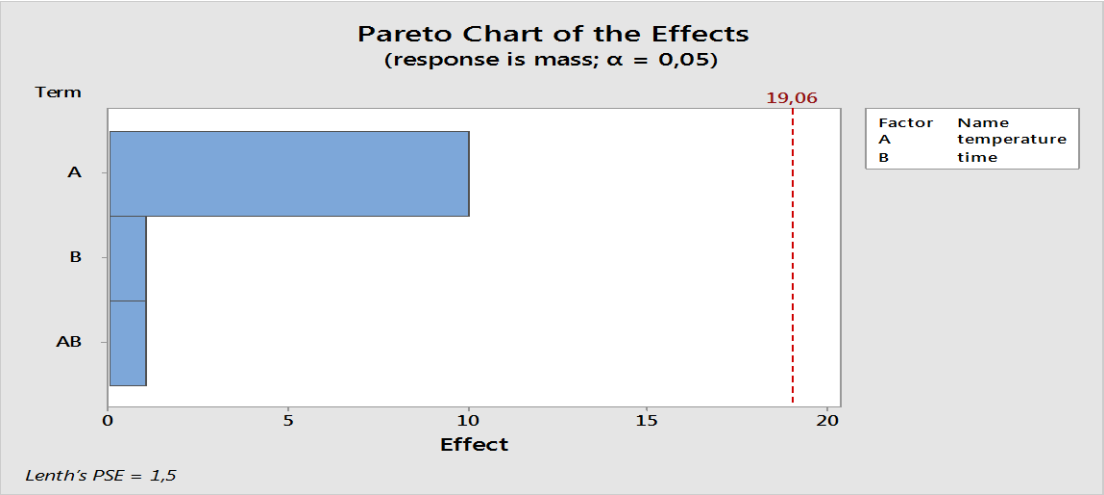

Figure 3: Pareto chart of effects that can influence the first extraction

Table 4: Parameters of the first extraction to confirm the working gap

Samples	Time (min)	Temperature (˚C)	Mass of extracted oil(g)	Volume of extracted oil (ml)
1	15	110	105	108.5
2	60	100	Very low	Very low

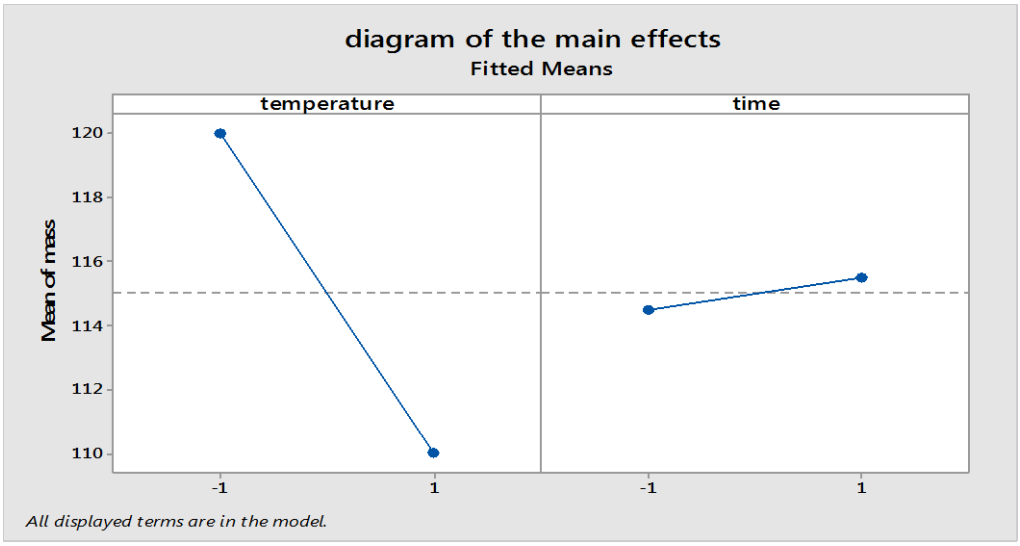

Figure 4: Diagram of the main effects of the reaction

According to the diagram above we can say that the time have a light influence during the reaction, what allows minimizing the losses in energy while decreasing the duration of cooking during the extraction of the oil.

So, according to this diagram and by referring to the table containing the other chosen points, we can conclude that the best points of the extraction which we have to make are (110 °C, 30min).

3.4.3. Diagram of interactions

Because both rights possess different angular coefficients (**figure 5**), we cannot neglect the interaction between both factors. It means that by varying the temperature either the time each alone, we cannot obtain satisfactory results.

3.5. Conclusion of the plan of experience(experiment) of the first reaction of extraction

According to the foreground of experience make for the reaction of extraction which depends on two essential factors (temperature, time) and according to the analysis made outside the working interval, we can

conclude that the best points to be kept during our modus operandi of which the purpose to have a better extraction are (110 °C, 30 min).

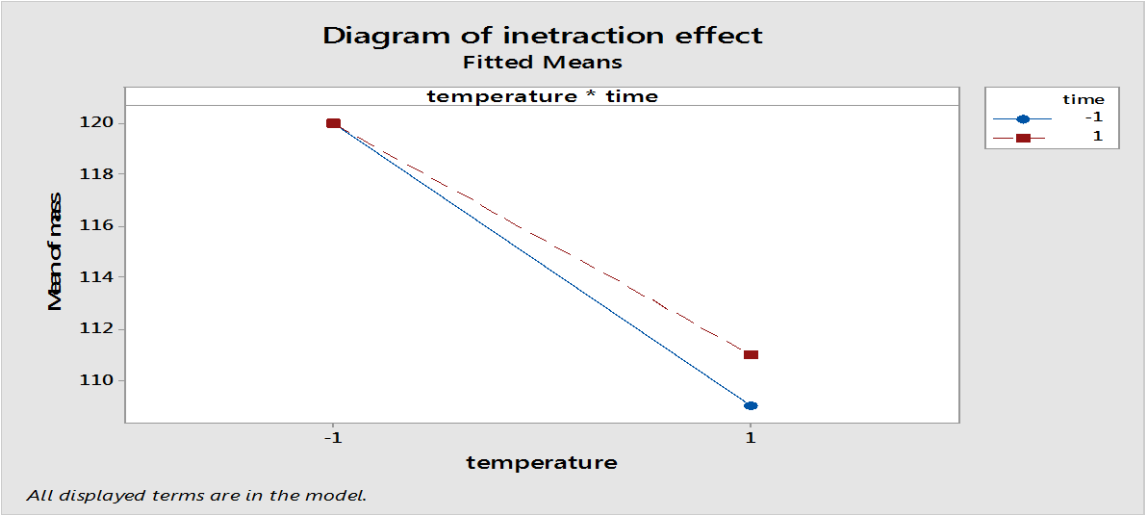

Figure 5: Diagram showing the influence of the interaction between temperature and time

The extremes of the interval of which we worked had significant results, but our purpose was to minimize the losses in energy which can be generated by working at high temperature either higher time. Since then, we chose the other working points which gave better results in 110 °C and 30 min.

4. Results and discussions of the 2nd extraction of oil from chicken skin

4.1. Variables identification

As well as the first extraction, the two factors that influenced our experience are: temperature and time (**table 5**).

Table 5: Second reaction parameters values

Temperature (°C)	Time (min)
110	6
120	8

4.2. Experimental design

So we have two factors with two levels each. There are four possible combinations (**table 6**):

Table 6: Possible combinations for the different factors (Second reaction)

Samples	A (°C)	B (min)	Mass of extracted oil (g)	Volume of extracted oil (ml)
1	110	6	75	65.5
2	120	6	74	72.5
3	110	8	65.5	62.5
4	120	8	73	70

With A = Temperature and B = Time

4.3. Analysis of variables influence

We will proceed to three analyses, effect of temperature, time and there interaction on our reply [mass (or volume) of oil (or fat) extracted] can be measured as follows:

- *Analysis of the effect of temperature*

We can conclude from the result that, the variation of temperature to a maximum or minimum value has an influence on the mass of the extracted oil or grease. The percentage of his influence is 4.56%.

- *Analysis of the effect of time*

We can conclude from the result, that time has also an influence on the mass of extracted oil or grease in comparison with the influence of temperature, when the time increases the mass of extracted oil decreases little. The percentage of the time influence is 7.3%. Time has a greater influence than that of the temperature.

- *Analysis of the effect of both temperature and time*

After determining the necessary combinations we obtained important results (**table 7**):

Table 7: Combination of factors with their interaction

Samples	A (°C)	B (min)	A*B	M′(g)
1	110	6	+	75
2	120	6	-	74
3	110	8	-	65.5
4	120	8	+	73

We can conclude from the table that the interaction of two variables have an influence of 5.91% on the extracted oil (M' = masse of the extracted oil).

- *Analysis of results of the combinations*

The mathematical model representing the first stage of experimental plan is written in the form:

$$M'(g) = a_0 + a_1 A + a_2 B + a_{12} AB$$

Where A and B are the temperature and time variables.

a_0, a_1, a_2, a_{12} are the polynomial coefficients. (a_0=71.9; a_1=1.625; a_2= -2.625; a_{12}= 2.125)

The polynomial model of equation become in the form:

$$M'(g) = 71.9 + 1.625A - 2.625B + 2.125AB$$

4.4. plotting curves of the second extraction

4.4.1. Pareto chart

When the tests are carried out and that we have all the responses, we can proceed to the mathematical or statistical analysis.

Of all the factors studied, and the selected level of confidence (α = 0.05), temperature (A) appears as a very influential factor, time (B) and interaction (AB) do not have to significant effect on the response (**figure 6**).

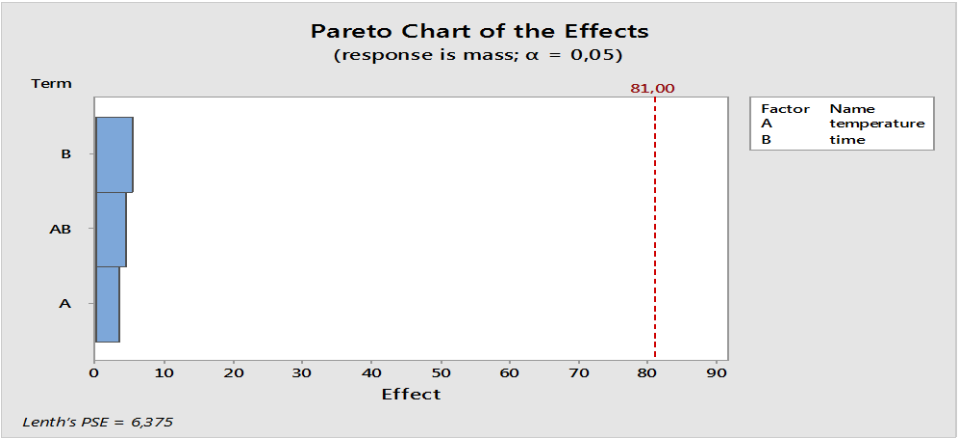

Figure 6: Pareto chart of effects that can influence the second extraction

From this diagram, it is clear that both parameters and their interaction have an influence, which is seen at the level of the masses extracted that are normal if we consider that in the first reaction was extracted the majority of the fat needed. We can choose the temperature and time that can be available for the second extraction (**table 8**).

Table 8: Parameters of the second extraction to confirm the interval of work

Samples	Time (min)	Temperature (˚C)	Mass (g)	Volume (ml)
1	7	110	44	39.5
2	7	115	36	29.5

4.4.2. Diagram of the main effects

The diagram of the main effects (**figure 7**) is used to determine the influence of all the factors on the amount of oil extracted while representing the average mass extracted at both levels of factors.

From the diagram above we can say that both factors influence. Thus, with reference to the table with the other selected points, we can conclude that the best points available for the second extraction of oil are (110 ˚C, 6min).

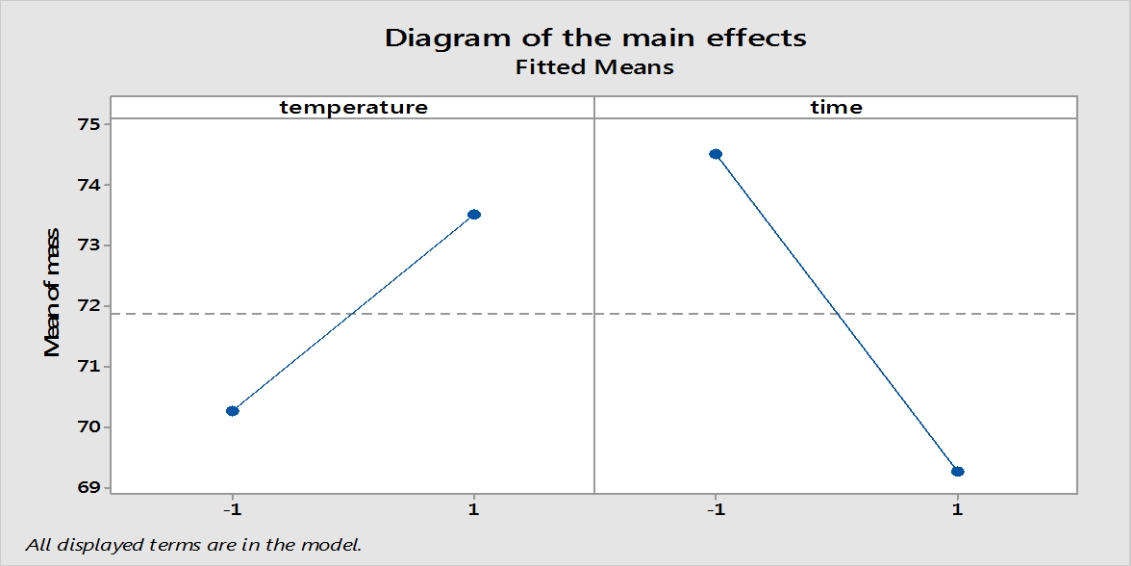

Figure 7: Diagram of the main effect of the reaction

4.4.3. Diagram of interactions

Since the two lines have different angular coefficients (**figure 8**), we can't neglect the interaction between the two factors. This means that by varying the temperature or time each alone, we can't achieve satisfactory results. According to the first experimental design produced for the extraction reaction that depends on two main factors (temperature, time) and according to the analysis done outside the interval of work, we can conclude that the best points keep in our procedure with the aim of having a better extraction are (110 ˚C, 6 min).

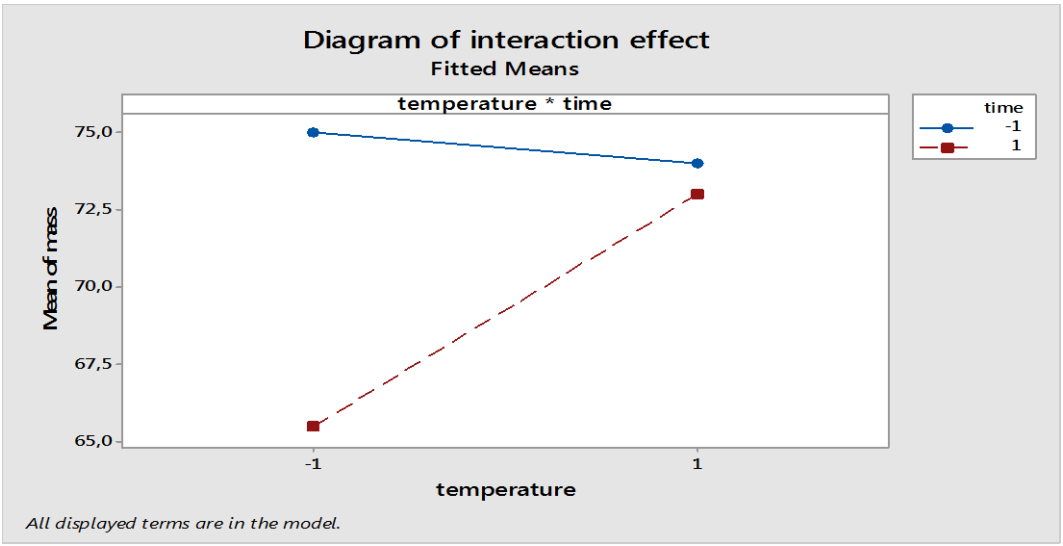

Figure 8: *Diagram showing the influence of the interaction between temperature and time*

Conclusions

The purpose of this first biodiesel synthesis step in the whole process was the determination of extreme parameters that must be used later for optimal extraction.

According to the manipulation applied, it happened to be set for the first reaction points (110 ˚C, 30 min) and the second reaction (110 ˚C, 6 min).

The yield of fat extracted from chicken skin in our project was very important (97.5 %) in comparison with other projects that have founded 80% [18], [20].

We performed multiple trials during the first stage of the synthesis of biodiesel to properly target temperature and time in order to have maximum oil extraction that will be used in subsequent steps.

Acknowledgements-The authors would like to thank the administration for their financial support to accomplish this work

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