EVALUATION OF THE PARAMETERS AFFECTING THE SOLVENT EXTRACTION OF SOYBEAN OIL

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ABSTRACT

Soybean is grown primarily for its protein content and secondarily for its oil; it is an excellent protein supplement for enriching cereal diet. The primary processing of soybean before oil extraction include cleaning, cracking, flaking and conditioning, these ruptures the oil cells, for efficient extraction. Most modern oil extraction industries use the solvent extraction process and the solvent commonly used is the food grade hexane. In this paper detail experiments were carried out on the various processing parameters affecting the solvent extraction of soybean oil. Among the process factors considered are: particle size, flakes thickness, temperature of extraction, extraction time, flakes and particle moisture content. The results showed that, at a particle size of 2mm, flakes thickness of 0.25mm, moisture content of 12-13%, temperature of 69 ^{0}C and the extraction time between 3½ and 4 ½ hours, the oil yield was maximum.

Keywords: soybean, solvent, extraction, miscella, flakes, temperature.

INTRODUCTION

Since the beginning of history, people have made use of the oils obtained from seeds and nuts. The principal use of these oils is as food. They are eaten raw and cooked, are a useful ingredient in baking and serve as a medium of transfer of heat in frying. Oils are source of calories and of fat - soluble vitamins, (Joules and James, 1990).

Soybean (Glycin Max) originated in China. It is grown primarily for its protein content and secondary for oil. Processing soybean yields a number of other products as well. Soybean is an excellent protein supplement for enriching cereal diet (Williams and Akiko 2004).

There are various methods that can be used to process soybean seed into oil and meal Hydraulic presses, screw presses, extrusion methods and solvent extraction method. The methods by which a particular oil seeds are extracted depend on the type of seed, the seed characteristics and the oil content of the seed, (Iwe 2003, FAO 1992, and Lawson 1999). Seeds such as soybean seed with low oil content are better extracted using solvent extraction method. Most modern oil extraction industries in Nigeria use the solvent extraction process. The solvent commonly used is food grade hexane.

In the first stage of this process, seeds are cleaned; destoned, cracked, conditioned and flaked. The flakes are placed in a vapour sealed percolating extractor. The solvent is then percolated through perforated plate; crude soybean oil is obtained after the hexane is removed from the miscella. Flakes thickness from 0.02 to 0.06mm decreases the extraction rate eighty times (Erickson *et al*. 1980). The advantages of solvent extraction over other methods of oil expression include, higher oil yield (about 95% of the oil content could be obtained), larger processing capacity, solvent extraction also gave oil that many considered to be of superior bleaching quality, lower refining losses, reduced susceptibility to rancidity and better retention of fat - soluble vitamin, (Lager, 2006, Robbellen *et al.,* 1989 and Goss, 2004).

This study evaluates the various parameters, (such as particle size, flakes thickness, extraction time and temperature and moisture content) that affects the solvent extraction of soybean oil and meal product.

METHODOLOGY

Materials

The soybean used for this study was obtained from local farmers in Gboko, Benue state in Nigeria and the type used is the yellow type because it is the most common and readily available variety grown in Nigeria. Similarly, the equipment used for the preparatory stage of the seed were gotten from Vegetable Oil Division of JOF Ideal Family Farms Ltd; Owo, Ondo State.

Methods

The parameters of processing considered in this study were those based on the literature review, practical experience and preliminary laboratory investigations on solvent extraction of soybean oil. These parameters include particle size, flakes thickness, extraction time, temperature, and particle and flakes moisture content. In determining each of the above parameters, Association of Official Analytical Chemists (AOAC) standard in Luthra (2004) were adopted.

The first phase of the experiment involves the determination of the particle size of the soybean as well as the flakes thickness before extraction process.

In determining the particle size, the roller clearance were adjusted and checked by the use of feeler gauges to obtain the following values, 0.1, 0.2, 0.3, 0.4, and 0.5 up to 1.5mm. Consequently, the soybean seed were fed into the cracking machine to obtain corresponding values of the particle size of the soybean;

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the particles were then measured using the micrometer screw gauge.

After this, a given particle size, cracked and conditioned soybean seed obtain from the process above were fed into the flaking machine to achieve the various flakes of desired thickness. The samples taken from different points along the length of the rolls were then checked for thickness using the micrometer screw gauge.

The second stage of the experiment involve the determination of the effect of flakes thickness, time, temperature, moisture content on oil yield of soybean seed.

To achieve the effect of flake thickness on oil yield, five grams of flakes of varied thicknesses were wrapped in a filter paper and place in the thimble of an extractor of the soxhlet apparatus. The extraction flask of the apparatus was filled with hexane up to 150ml and heated to the temperature of about 69^{0}C; the experiment was allowed to run for 2 hours after which the extracted oil was emptied into a beaker to remove traces of solvent and moisture. After this process, the oil was placed in desiccators to cool. After cooling, the content of the beaker was weighed and the percentage of the oil obtained calculated and the residual oil yields determine using.

$$\text{Oil yield} = \frac{\text{weight of extracted oil X 100\%}}{\text{Weight of sample}} \quad \ldots\ldots\ldots\ldots \quad (1)$$

$$\text{Residual oil (\%)} = \text{(oil content – extracted oil) \%} \quad \ldots\ldots\ldots\ldots \quad (2)$$

Following closely, the effect of extraction time on oil yield was investigated (Table-1).

Table-1. Effect of Extraction time on oil yield.

Extraction time (hours)	**Oil yield** (%)
0.5	10.60
1.0	11.50
2.0	13.37
2.5	17.98
3.0	15.18
3.5	16.97
4.0	16.07
4.5	15.10
5.0	15.00

E = 0

Table-2. Effects of temperature on oil yield.

Extraction temperature (^{0}C)	**Oil yield** (%)
60	5.03
61	6.18
62	7.33
63	8.51
64	9.62
65	10.77
66	11.90
67	13.97
68	15.97
69	15.98
70	15.01

E=0.02

By keeping all other factors constant, the extraction time is varied thus ½, 1, 1½, 2, 2½, 3, 3½, 4, 4½, hours. The extraction process was carried out as in above. In case of the effect of the temperature of extraction, this was varied through 60, 61, 62, 63, 64, 65, 66, 67, 68, 69 to 70^{0}C and the usual extraction process was carried out and the percentage of oil extracted calculated, (Table-2).

Finally, the effect of particle moisture content on flakes thickness and the effect of flakes moisture content on oil yield were investigated this is as shown in Table-3 and Table-4 respectively.

Table-3. Effects of particle moisture content on flakes thickness.

Particle moisture content X	**Flakes thickness** (mm) **based on data Y1**	**Flakes thickness** (mm) **based on equation Y2**
10	0.30	0.23
11	0.28	0.27
12	0.25	0.31
13	0.38	0.35
14	0.39	0.40
15	0.40	0.43
16	0.45	0.48
17	0.48	0.51
18	0.50	0.55
19	0.56	0.59
20	0.68	0.62
21	0.70	0.66
22	0.71	0.70

E = 0.03

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By gradually increasing the moisture content of both the particles and flakes obtained initially in this experiment, starting with 10% through 13, 14, 15, 16, 17, 18, 19, 20, 21 to 22% and 25% for both the particles and flakes respectively their effect were determined. All other factors remain constant.

Table-4. Effects of flakes moisture content on oil yield.

Flakes moisture content	Oil yield (%)
9	14.85
10	15.00
11	14.70
12	14.38
13	14.06
14	13.74
15	13.42
16	13.09
17	12.77
18	12.45
19	12.13
20	11.81
21	11.41
22	11.16
23	10.84
25	10.20

E = 0.07

RESULTS AND DISCUSSIONS

Figure-1 shows the variation of soybean particle size on the flakes thickness. With the average particle size of 0.18mm, the resulting average flakes thickness gives 0.15mm. In a similar vein, when the particle size changes to 0.22mm the flake thickness is 0.18mm. In all, linear relationship exists between the two variables. Increase in the particle size leads to increase in the flakes thickness and vice - versa. The regression analysis of the result, Table-5 gives the equation y = 0.031x + 0.133, and the variables are highly correlated (R^2 = 0.98).

Figure-2 illustrates the effect of flakes thickness on oil yield. It could be seen from the Figure that the optimum flakes thickness to give the maximum oil yield is 0.25mm. The oil yield at this point is 15.97%. However, as the flakes thickness reduces below this point, the oil yield decreases. This contradict the popular believe or expectation that the thinner the flakes thickness the higher the oil yield. The reason for this observation is due to the less resistance offered by the flakes to the flow of the solvent. Hence, it is the “surface washing” of the flakes by the solvent instead of the solvent percolating into the flakes. This observation agrees with the report of Robbelen *et al.* (1989).

On the other hand, the decrease in the oil yield observed when the flake thickness was above 0.25mm is due to decrease in the surface area of the flakes. Also, the effect of time on oil yield was examined; Table-1 shows that at extraction time of 2½ hours maximum oil yield is obtained while below and above this time the oil yield reduces

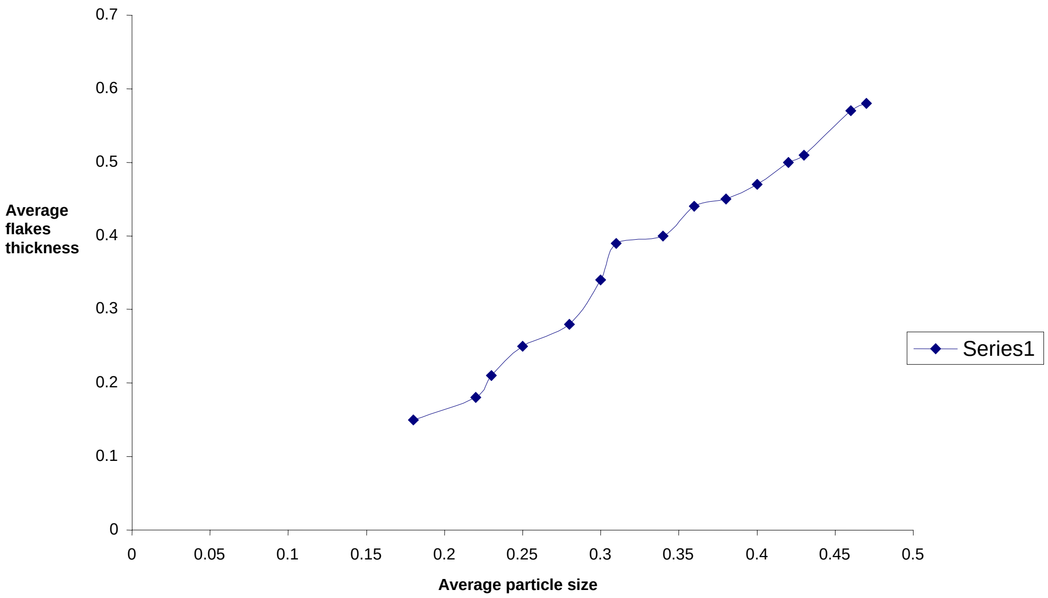

Figure 1 Effect of particle size on flakes thickness

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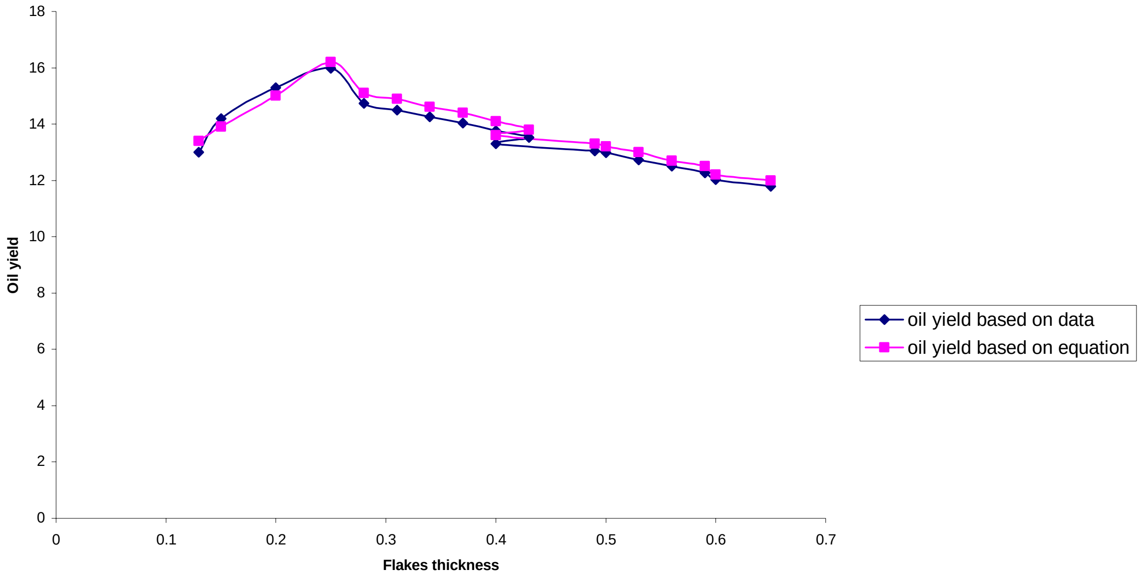

Figure 2, effect of flakes thickness on oil yield

In case of temperature, Table-2 clearly defined a linear relationship, the higher the temperature the higher the oil yield. However, it is dangerous to increase the temperature of the extraction solvent beyond its boiling point (69^0C) due to incident of explosion.

Finally, the effect of particle moisture content (m.c) on flakes thickness and flakes moisture content on oil yield reveal that at 12% particle m.c, the flakes thickness obtained is 0.25m. Similarly, at 10% m.c the oil yield is maximum (15%). When the m.c is 20%, oil yield reduces to 11.81% as shown in Table-3 and Table-4 in the above result. The above observation is because hexane is highly insoluble in water; hence, with high moisture content the extraction efficiency of the solvent will be drastically reduced, therefore poor oil yield results.

The regression analysis carried out shows a significant relationship between the variables and the R^2 values obtained in each case are good enough to describing the degree of variability between the variables, high correlation also exist between the variables in each case. The regression equations developed are good enough to predict the value of Y when the value of X is known (see Table-5)

Table-5. Result analysis and calculations.

S/No		Regression equation	r values	R^2
A	Particles size versus flakes thickness	$y = 0.031x + 0.133$	0.98	0.98
B	[i] Flakes thickness versus oil yield (thickness between 0.15 mm and 0.25 mm) [ii] Flakes thickness versus oil yield (flakes thickness between 0.28 and 0.05)	$y = -0.65x + 10.4$ $y = -0.65x + 0.25$	0.96 0.96	0.98 0.97
C	Flakes thickness versus residual oil	$y = 15.3x - 2.8$	0.99	0.98
D	Extraction time versus oil yield	$y = 1.7x + 9.9$	0.99	0.99
E	Temperature versus oil yield	$y = 1.15x - 63.8$	0.10	0.1
F	Particle m.c. versus flakes thickness (10-12%)	$y = 0.03x + 0.6$	-0.99	+0.97
G	[i] Particle m.c. versus flakes thickness (13.22% m.c.) [ii] Flakes m.c. versus oil yield	$y = 0.04x + 0.21$ $y = 0.32x + 18.2$	+0.97 0.10	0.96 0.10

SUMMARY AND CONCLUSIONS

Several parameters affecting solvent extraction of soybean oil were investigated. Amongst these are; particle size, flakes thickness, extraction time, extraction temperature and moisture content of soybean particles and the flakes. The effects on oil yield were clearly shown. In order to maximize oil yield of soybean, it is hereby recommended that; the flakes thickness should not be too thin or too thick, because this will result in low oil yield; it should be about 0.25mm thick for optimum oil yield. Also, the extraction time should be maintained between $3^{1/2}$ hours and $4^{1/2}$ hours, below this time, most of the oil would not have been removed while above this time in question, extraction of the available oil would have stopped. The temperature of extraction should not be greater than 70^0c ((i.e., $69^0C \leq x \leq 70^0C$), at these temperatures, incident of explosion will be avoided. Finally, for maximum oil yield food grade hexane is recommended.

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