Process Optimization of Oil Expression from Sesame Seed (*Sesamum indicum* Linn.)

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ABSTRACT

Sesame seed (*Sesamum indicum* Linn) is a tropical economic crop with high oil yield. A study was carried out to establish the degree of influence of moisture content, duration and temperature of roasting on oil expression from this crop using an oil expeller. Effects of these parameters were used to develop model equations, optimize oil yield and quality. 4 levels each of moisture content, roasting duration and temperature were used for the experiment, giving a total of 64 samples. Expressed oil was recorded as yield while free fatty acid, oil impurity and color were the criteria used in determining oil quality. Data were analyzed, employing multiple regression technique to generate mathematical models. Oil yield was maximized while oil free fatty acid; color and impurities were kept at acceptable levels. Mean oil yield, free fatty acid, impurity and color were 34.78 %, 2.57 %, 0.22 % and 6.7 respectively. The optimum moisture content, roasting duration and roasting temperature were 4.6 % wet basis (wb), 13.0 min. and 124.2 ^{o}C. These combinations gave 50.4 % oil yield, 1.1 % free fatty acid, 0.1 % oil impurity and 6.2 LUY. Error in prediction is not significance at P > 0.05. Expression of sesame seed at the obtained optimum parameters guarantees high yield and good quality virgin oil.

Keywords: Sesame seed, oil expression, expeller, moisture content, roasting duration, roasting temperature, optimization

1. INTRODUCTION

Edible oils are derived from animals and plants (Sangha *et.al* 2004). Oils from plants are classified as vegetable oil. The largest sources of vegetable oils are annual plants, which include soybeans, corn, cottonseed, groundnut, sunflower, rapeseed, melon and sesame seed (Frank, 1998, O'Brien 1998). Other sources are oil bearing perennial plants such as olive, coconut, shear, cashew and palm. Sesame seed is rich in oil content with about 53 % quality edible oil, 42 % cake and 5 % moisture seed (Akinoso, 2002). The report also revealed that oil content varies with genetic and environmental factors.

Sesame seed oil is a natural salad oil, requiring little or no winterization, and is one of the few vegetable oils that can be used directly without refining (Sudhir *et. al.*, 1996; Gandhi, 1998). The seed cake is a good source of protein supplement in the animal feed industry. Sesame seed are pear-shaped, ovate, small (about 2.5-3mm in length, 1.5mm in width), slightly flattened, and thinner at the hilium. Weight of 1000 seeds is approximately 3 g. The color varies; it is either white, yellow, reddish brown or black. Light-colored seeds yield better quality oil than dark but lower oil content (Olayanju , Akinoso, and Oresanya, 2006).

Applied pressure, heating temperature, heating duration, moisture content, particle size, handling and storage are factors influencing yield and quality of vegetable oil expression (Weiss, 2000). The degree of influence varies with kind of oilseeds and method of oil expression (Akinoso, 2006).

Effects of some of these parameters on yield and quality of oil expressed from sesame using expeller were investigated. Moisture content, duration of heat treatment and pre heating temperature were studied. Model equations were developed to optimize oil expression using linear programming.

2. MATERIALS AND METHODS

Sesame seed samples (NCRI-98-60) variety was collected from National Cereals Research Institute (NCRI) Badegi Nigeria. The seeds were manually cleaned to remove foreign materials. A factorial experimental design was used in the test, giving a total of 64 samples. Initial moisture content of the sample was determined using (ASAE) 1998 standard for oil seed. 3 kg each of sesame were conditioned to desired levels of moisture content 5.3, 7.3, 12.1 and 16.7% all on wet basis using equation 1.

$$Q = A(b-a) \Big/ (100-b) \quad \ldots\ldots\ldots\ldots\ldots\ldots 1$$ (Akinoso, 2006)

where

A - Initial mass of the sample
a - Initial moisture content of the sample, % wet basis (wb)
b - Final (desired) moisture content of sample % wb
Q - Mass of water to be added kg.

They were also heated at 70, 90, 110 and 130 ^{o}C for 5, 10, 15 and 20 minutes roasting duration. Heat treatment was achieved by Igbeka (1982) method. FIIRO developed vegetable oil expeller was used for oil expression. The expeller capacity is 15 kg/hr, and powered by a 7.5 kW, 3 phase electric motor with in-built speed reduction gear. It was run at 45 rpm. The expressed oil was collected and left to stand for 96 hours and volume measured. Recorded volumes of the oils were multiplied by sesame oil density at 30 ^{o}C (918 kg/m^{3}) as determined by Weiss (2000), to convert to weight. Percentage oil yield was calculated by dividing the oil weight by weight of expressed sesame i.e 3kg.

Percentage of free fatty acid (ffa) in each sample of sesame oil was calculated as oleic acid using AOCS method for ffa Ca 5a-40. About 7 g of oil sample was put in 250 ml flask in addition with 50 ml neutralize alcohol. The mixture was titrated with 0.25 N NaOH with vigorous shaking until permanent faint pink appears and persists for 60 seconds. Millimeter of 0.25 N NaOH used in the titration correspond to the percentage of free fatty acids calculated using equation (2).

$$\mathrm{FFA}\,(\%) = \mathrm{V} - \mathrm{B} * \mathrm{N_f} * 28.2 \Big/ W \ldots\ldots\ldots\ldots\ldots\ldots 2$$

where
FFA = Free Fatty Acid
V = Volume of the NaOH consumed (ml.)
B = Volume of NaOH consumed during blank titration (ml.)
W = Weight of oil sample (g)
N_f = Normality of NaOH factor

Levels of moisture impurity in the extracted oils were determined by air oven method in conformity with AOCS Ca 2c-25. A representative sample of 5 g is weighed into a dried, tarred moisture dish and dried in the oven for about 30 minutes at 100 ^{o}C and repeated until a constant weight is attained. The loss in weight is calculated as the moisture and volatile matter. The color of the oils was determined by American Oil Chemists Society method Cc 13e-92 (AOCS, 1994), utilizing a Lovibond Tintometer (Model F manufactured by Tintometer Ltd England).

Oil yields from the samples were recorded as percentage of raw material while free fatty acid (ffa) content; oil impurity and color were used as criteria for determining oil quality. Mathematical constructs were developed based on the empirical data to predict effects of moisture content, roasting duration and roasting temperature on oil yield, free fatty acid, impurity and color. A SPSS window 10.0 software packages was used to generate equations applying multiple linear regressions method. The optimum process parameters for oil expression were determined using simplex method of linear programming as reported by Belegundu and Chandrupatla (2003). An algorithm in BASIC language was developed to determine optimum process condition. Oil yield was maximized while free fatty acid content; oil impurity and color were kept at acceptable level. To validate the optimal parameters, the experiment was repeated at these conditions as suggested by Islau, *et al.,* (2002). The obtained results were compared with predicted values.

3. RESULTS AND DISCUSSION

Recorded oil yield varied from 12.85 to 51.86 % of raw materials, free fatty acid (ffa) varied from 1.05 to 4.54 %, oil impurity volatile at 105 oC varied from 0.10 to 0.40 % and oil color intensity varied from 5.8 to 8.3 lovibond unit yellow (LUY). Mean oil yield , free fatty acid, impurity and color were 34.78 %, 2.57 %, 0.22 % and 6.7 respectively (table 1).

Table 1: Summary of results of the experiments

Factors	Oil Yield (%)	Free Fatty Acid (%)	Impurity (%)	Color LUY
N	64.00	64.00	64.00	64.00
df	3.00	3.00	3.00	3.00
Minimum	12.85	1.05	0.10	5.80
Maximum	51.86	4.54	0.40	8.30
Mean	34.78	2.57	0.22	6.70
Stdev.	11.70	0.96	0.07	0.69

The developed model equations were stated as equations 3 to 6. The sign and magnitude of the coefficients indicate the effect of variable on the response. Negative sign of the coefficient indicate decrease in dependent variable when the value of that independent variable is increased while positive sign of the coefficient indicate increase in dependent variable when the value of that independent variable is increased. Significant interaction suggests that the level of one of the interaction variables can be increased while that of other decreased for constant value of the response. As shown in equations 3 to 6, it is obvious that the degree of independent variables influence on oil yield and quality are not equal.

$$OY = 38.485 - 4.944x_1 + 0.446x_2 + 0.207x_3 + 0.118x_4 - 0.01722x_5 - 0.00009972x_6 + 0.03032x_7 + 0.005413x_8 + 0.0007251x_9 \geq 51.7 \quad \ldots\ldots 3$$

$$FFA = -1.74 + 0.611x_1 + 0.01028x_2 + 0.03067x_3 - 0.01133x_4 + 0.0008905x_5 - 0.0001472x_6 - 0.002173x_7 - 0.001664x_8 - 0.0003039x_9 \leq 1.1 \quad \ldots\ldots 4$$

$$OI = 0.306 + 0.03324x_1 - 0.006115x_2 - 0.002949x_3 - 0.0004486x_4 + 0.00006433x_5 + 0.00001027x_6 + 0.00009425x_7 - 0.0001609x_8 + 0.00002153x_9 \leq 0.12 \quad \ldots\ldots 5$$

$$CO = 6.2 + 0.01912x_1 + 0.03697x_2 - 0.02795x_3 - 0.003636x_4 - 0.0004554x_5 + 0.000141x_6 - 0.0006899x_7 + 0.001799x_8 - 0.0000597x_9 \leq 5.7 \quad \ldots\ldots 6$$

where

OY = Oil Yield (%) FFA = Free Fatty Acid (%)

OI = Oil Impurity (%) CO = Oil Color (LUY)

x_1 - MC = Moisture Content (%wb)

x_2 - RD = Roasting Duration (min.)

x_3 - RT = Roasting Temperature (^oC)

x_4 - MC^2 x_5 - RD^2 x_6 - RT^2

x_7 - MC*RD x_8 - MC*RT x_9 - RD*RT

Moisture content has highest influence on sesame seed oil yield; follow by roasting duration and roasting temperature in that order equation 3. To increase oil yield, moisture content is reduced while roasting duration and roasting temperature are increased. According to Weiss (2000), initial moisture content of sesame seed determines the cooking temperature and time. Sivakumaran *et al,* (1985), Young e*t al,* (1995) and Tunde-Akintunde (2000) use mathematical models for predicting oil expression from peanut, sesame seed and soybean respectively, and found that moisture content has the greatest influence on oil yield. And also that increase in moisture content decrease oil yield, which is in agreement with equation 3.

Equations 4 to 6 illustrate quality criteria. In equation 4, moisture content, roasting duration and temperature carry positive signs but moisture content is the most significant. 2nd order of roasting temperature and interaction between roasting duration and temperature are negligible using 3 significance figures. For oil impurity volatile at 105 ^{o}C (eqn. 5), moisture content is positive while roasting duration and temperature are negative. All the 3 parameters are important at 3 significance figures. As reflected in equation 6 for oil color, moisture content and roasting duration are positive while roasting duration is negative. It is interesting to note that unlike other models where moisture content has greatest influence; roasting duration effect is the most significant. This suggest that, changes in roasting duration will noticeable dictate sesame oil color more than roasting temperature and moisture content.

Optimum condition was achieved at seed moisture content of 4.6 % wet basis, roasting time and temperature of 13.0 min. and 124.2 ^{o}C respectively. At these conditions, oil yield was 50.4% of raw material, equivalent to 90.1 % efficiency of oil expressed. Free fatty acid was 1.1%m/m while oil impurity was 0.1 %m/m and color rating was 6.2 lovibond unit yellow.

Using hydraulic press, Young-kyoo and Jeong, (1995) reported optimum temperature, pressure and moisture content for expression of sesame seed oil to be 44.4 ^{o}C, 37.8 Mpa and 2.25 % respectively, which gave efficiency of oil expressed as 81.7 %. The optimum oil yield was less than 90.14 % obtain from this study. According to Swern (1982), optimum moisture of cooked seed varies widely with variety of seed and the method to be used for expression. Therefore, difference in results may be traced to marginal roasting temperature, moisture content and method of oil expression.

The optimum moisture content of 4.6 % wet basis was less than the minimum moisture content of 5.3 % wet basis considered in this study. Sesame seed contain about 5 % moisture content (Akinoso, 2006) and most sesame seed find in Nigeria markets are sold at about this moisture content level. Therefore, drying of sesame seed is also necessary. The obtained optimum roasting duration (13.0 min) and roasting temperature (124.2 ^{o}C) are within the study range.

As shown in table 2, percentage errors recorded from predicted optimum conditions were 1.5, 0.0, 0.0 and 5.0 for oil yield, free fatty acid, oil impurity and color respectively. At 5% level of significance, all the optima parameters as predicted are permissible. Thus appropriate to be applied.

Table 2: Verification of sesame seed oil optimum parameters

Responses	Predicted	Empirical	% Error
Oil Yield	50.40 ± 3.89	51.10 ± 2.46	1.50 ± 0.03
Free fatty acid	1.10 ± 0.08	1.10 ± 0.06	0.00 ± 0.01
Oil Impurity	0.10 ± 0.02	0.10 ± 0.02	0.00 ± 0.02
Color	6.20 ± 0.20	5.90 ± 0.21	5.00 ± 1.06

4. CONCLUSIONS

The optimum process parameters for expression of high yield, and good quality sesame seed oil are 4.6 % wet basis moisture content, 13.0minutes roasting duration and 124.2 ^{o}C roasting temperature, which give 50.4 % oil yield, 1.1% free fatty acid, 0.1 % oil impurity and 6.2 lovibond colour yellow.

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