Modeling of Oil Expression from Palm Kernel (*Elaeis guineensis* Jacq.)

Akinoso R.*[1] , J.C.Igbeka, [2] T.M.A. Olayanju [3] and L.K Bankole[1]

[1] Federal Institute of Industrial Research Oshodi (FIIRO),Cappa Bus stop, Blind Center Street, Oshodi Lagos, Nigeria. E mail akinoso2002@yahoo.com

[2] Department of Agricultural and Environmental Engineering, Faculty of Technology University of Ibadan, Nigeria.

[3] Department of Agricultural Engineering, College of Engineering , University of Agriculture, Abeokuta Nigeria.

ABSTRACT

Moisture content , duration and temperature of roasting are some of the critical parameters influencing oil expression. Effects of these parameters on palm kernel (*Elaeis guineensis* Jacq.) were determined to develop model equations. A 4 x 4 x 4 factorial design was used in the test resulting in a total of 64 samples. Each sample at moisture content 4.5, 5.9, 10.4, and 15.2 % all on wet basis (wb) and were roasted for 5, 10, 15 and 20 minutes each of which was carried out at temperatures of 70, 90, 110 and 130 ^{o}C. Data were analyzed, employing multiple regression technique to generate mathematical model. Adequacy of the model was authenticated by coefficient of determination R^2, F test and residual analysis criteria. The results obtained showed that oil yields decreased steadily with increase in moisture content . Increase in duration and temperature of roasting produced un-steady rise in oil yields . The maximum oil yield recorded was 47.0 % of the raw material equivalent to 94.7 % efficiency of oil expressed. This was achieved at kernel moisture content of 4.5 % wb, 5 minutes roasting duration and 130 ^{o}C roasting temperature. Mean oil yield was 25.8 % of the raw material. Coefficient of determination R^2 at 95 % confidence level of the predictive model was 86 %, probability of prediction F, was 37.2 %. Moisture content influence is the most significant.

Keywords: Palm kernel, oil expression, screw press, moisture content, roasting duration, roasting temperature, modeling.

1. INTRODUCTION

Oil can be extracted from many raw materials, but not all contain edible oil. Some contain poisons and unpleasant flavors (Frank, 1998). Edible oils are derived from animals and plants (Sagha *et.al.*, 2004). Oils from plants are classified as vegetable oils. 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 (Atiku *et. al*., 2004) There is a universal demand for vegetable oil due to its increasing domestic and industrial uses.

Oil content of vegetable oil-bearing materials varies between 3 and 70 % of the total weight of the seed, nut, kernel or fruit (Bachman 2004). The rate of vegetable oil consumption is increasing compared with animal fat due to its health implication (Akinoso,2006) .The industry is thus challenged to produce high quality oil products at reduced prices. Importance of oil crops as a vital part of the world's food supply is evidenced in world agricultural trade statistics (FAO, 2005). Oil is obtained from oilseed by either solvent extraction or mechanical expression or the combination of the two processes. For mechanical expression, hydraulic or screw press is employed. The oil is used locally for cooking, lighting and as body cream. It is also used for production of soap, cosmetic and margarine. Further processing improves the quality of the oil (Kheiri, 1985). Good quality edible oil is fresh, pure, free from odours, and any sign of rancidity. The acceptability of the products at world edible oil market depends on its ability to satisfy basic standard tests for fats and oil (Takakura, 2002).

Harvested palm bunches undergo processing stages of sterilization, stripping, digestion and palm oil extraction. Palm nuts and fibers are left as residue. The nuts are dried and cracked . It is separated into palm kernel oil (PKO), palm kernel meal (PKM) and water in proportionate composition of about 47 %, 49 %, and 4 % respectively (Akinoso, 2006). Due to economic importance of this crop, model equation was developed to predict oil yield at any given moisture content, roasting duration and temperature.

2. MATERIALS AND METHODS

The experiment was a 4 x 4 x 4 factorial design using Harper and Wanninger (1969) equation on experimental design (equation 1). Moisture content , duration of heat treatments and pre-heat temperature were independent variables while oil yield is the dependent variable. The design is shown in table 1. Obtained data from these experiments form the basis for model equation. Sixty four-experiment combinations were produced.

$$N = (L_1)(L_2)(L_3)------(L_m) \qquad \ldots\ldots\ldots\ldots.1$$

where
N = No of experiments - 64
L = Levels of independent variables – 4
m = No of independent variables - 3

Tenera variety of Palm kernel was obtained from Nigeria Institute for Oil Palm Research (NIFOR), Benin City. The kernel was cleaned manually to remove dirt and other foreign materials in compliance with Nigeria Industrial standard. The moisture content of the seed was determined using ASAE (1998) standard method for oil seed. Initial moisture content of palm kernel was 5.9 % wet basis. They were conditioned to desired levels. Sun drying at 34 ^{o}C for 12 hours reduced the initial moisture content of palm kernel to 4.5 % wb. Adding distilled water as calculated from equation 2 increased the moisture content of the seeds.

$$Q = A(b-a) \Big/ (100-b) \qquad \ldots\ldots\ldots\ldots\ldots\ldots 2$$

(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.

Each sample was sealed in a separate polyethylene bag. The samples were kept at 5 ^{o}C in a refrigerator for a week to enable the moisture to distribute uniformly throughout the samples. Four moisture content levels each were prepared. Roasting temperature stability was achieved by Igbeka (1982) method. The product's initial temperatures were raised to equilibrium with roasting temperature. This was achieved by wrapping them in polythene bags and placed in oven at desired roasting temperature level. These samples were later heated by spreading thinly on a heat conductor tray in an oven at a preset temperature. A thermometer was used to verify the oven temperature. Samples of 3 kg mass were heated in the oven at different temperature and time combinations. A stopwatch was used to monitor the time. Experiments were conducted at moisture contents of 4.5, 5.9, 10.4 and 15.2 % all on wet basis (wb). They were also heated at 70, 90, 110 and 130 ^{o}C for 5, 10, 15 and 20 minutes roasting duration.

Table 1: Experimental design

	Levels			
Parameters	1	2	3	4
Moisture Content % (wb)	4.5	5.9	10.4	15.2
Roasting Duration (min.)	5.0	10.0	15.0	20.0
Roasting Temperature ^{o}C	70.0	90.0	110.0	130.0

Fradex (Nigeria) manufactured palm kernel oil expeller model 500-G was used to express the oil. The expeller capacity was 70 kg/h powered by a 30 kW electric motor at speed of 70 rpm. The experimental procedure was by running the screw press for about 3 minutes before loading the pre-treated samples of palm kernel. The expressed oil was collected and clarified by allowing to stand for 96 hours. Volume of pure oil was measured using Simax Kavalier Stabil 2000 ml. measuring cylinder, three replicates of the experiment were done and mean values recorded. Recorded volumes were converted to weight using 904 kg/m^3 as palm kernel density at 30 ^{o}C as reported by Timms (1985). Soxhlet oil extraction method as reported by Fasina and Ajibola (1989) was applied to determine the initial oil content. This was used to calculate the percentage oil yield. A variation of ± 3 % was recorded in roasting temperature and it was associated with heat conductivity property of palm kernel. Also efficiency of the machine might influence the final result. However, the same oil expeller was used for all samples thus the envisaged error will be general.

Mathematical constructs were developed based on the empirical data to predict effects of moisture content, roasting duration and roasting temperature on oil yield. A SPSS window 10.0

software packages was used to generate equation applying multiple linear regressions method. Adequacy of the model was authenticated by coefficient of determination R^2, F test and residual analysis criteria.

3. RESULTS AND DISCUSSION

The percentage oil content of tenera variety of palm kernel used for this experiment as determined by soxhlet method was 49.6 %. Maximum oil yield expressed from the 3 kg palm kernel was 1560 ml (table 2) equivalent to 47.0 % of the raw material and 94.7 % efficiency of oil expressed. This was achieved at kernel moisture content of 4.5 %wb, 5 min roasting duration and 130 ^{o}C roasting temperature. Minimum oil yield from the same quantity was 310 ml equivalent to 9.3 % of the raw material and 18.8 % efficiency of expressed oil (table 2). This was achieved at kernel moisture content of 15.2 % wb with roasting duration and time of 5 min and 70 ^{o}C respectively .. The mean oil yield was 861ml., equivalent to 25.8 % of raw material. Within the range of this study, recorded margin between the maximum and the minimum palm kernel oil was 37.7 % equivalent to 1250 ml. That is about 416 liters difference in oil yield from 1000kg (1 tonne) of palm kernel.

Maximum expression efficiency of 94.7 % recorded for palm kernel oil was an improvement on 64 % reported by Ajibola (1989) for same kernel oil heated at 88.3 ^{o}C roasted for 9.8 min. and expressed at 25 MPa using hydraulic press. It is also higher than 88.4 % oil yield from soybeans reported by Guderjan *et al.* (2005) using electric field treatment. The difference in obtained results may be traced to methods of oil expression and efficiency of the equipment. Screw press (expeller) was used for oil expression in this experiment while Ajibola (1989) applied hydraulic press.

As reflected in table 2, it is apparent that oil yield varies with treatment parameters. Palm kernel oil yield decreased with increase in moisture content, and increases with increases in roasting duration and temperature. The observed variation in the oil yield with these parameters may be due to the optimum level for the appropriate physicochemical changes in the oilseed.

Model equation for predicting palm kernel oil yield is stated as below;

$$\mathrm{OY} = 22.174 - 4.333\mathrm{MC} + 1.336\mathrm{RD} + 0.294\mathrm{RT} + 0.219\mathrm{MC}^2 - 0.006094\mathrm{RD}^2$$

$$+ 0.0005652\mathrm{RT}^2 + 0.002837\mathrm{MC}*\mathrm{RD} - 0.01917\mathrm{MC}*\mathrm{RT} - 0.01073\mathrm{RD}*\mathrm{RT} \ldots\ldots\ldots 3$$

(R= 0.927, R^2 = 0.859 S =4.1273)

where

OY = Oil Yield %
MC = Moisture Content (%wb)
RD = Roasting Duration (min.)
RT = Roasting Temperature (^{o}C)
R = Regression Coefficient
S = Standard Error of Estimate

Table 2: Summary of effect of process parameters on palm kernel oil yield

MC%	RD	RT	OY(ml.)	OY%	EE%
4.5	5	70	760	22.90	46.14
4.5	5	90	1335	40.20	80.99
4.5	5	110	1280	38.56	77.70
4.5	5	130	1560	47.00	94.70
4.5	20	70	1470	44.29	89.25
4.5	20	90	1485	44.73	90.12
4.5	20	110	1255	37.11	75.78
4.5	20	130	1265	38.18	76.80
15.2	5	70	310	9.33	18.79
15.2	5	90	570	17.16	34.86
15.2	5	110	480	14.46	29.14
15.2	5	130	510	15.36	30.96
15.2	20	70	600	18.06	36.40
15.2	20	90	575	17.33	34.19
15.2	20	110	555	16.72	33.69
15.2	20	130	550	16.57	33.39

where

MC – Moisture Content % wet basis
RD – Roasting Duration (min.)
RT – Roasting Temperature ^{o}C
OY – Oil Yield
EE – Express Efficiency %

As reflected in the equation, at all the three independent variables, second order derivatives and interactions between the variables are significant. The analysis in table 3 show that coefficient of determination R^2 is high (85.9 %) at 95 % confidence level, while probability of prediction (F) was 36.51%. Estimated error of $\pm$ 4.13 is predicted. Moisture content, 2nd order of roasting duration, interaction between moisture content and roasting duration, and interaction between roasting duration and roasting temperature are negative indicating oil increase with reduction in each values. While roasting duration, roasting temperature, 2nd order of moisture content, 2nd order of roasting temperature, and interaction between moisture content and roasting duration carry positive sign. That is, increase in any of them improves oil yield. From equation 3, moisture content has greatest effect on palm kernel oil yield among the independence variables. As a result, any variations in moisture content will significantly reflect in oil yield.

Table 3: Summary of data analysis of result for oil yield

Factors	Empirical	Predicted

N	64.00	64.00
df	3.00	9.00
Minimum (%)	9.33	12.79
Maximum (%)	47.00	43.39
Mean (%)	25.80	25.80
STDEV	13.10	11.70
F Test (%)		37.15
R^2 (%)		86.10
Stand. Error		4.13

Similarly, Khan and Hanna (1984), Adekola (1995) and Olajide (2000) model equations for predicting oil yield from soybean, coconut and groundnut respectively singled out moisture content as most significant factors among the studied parameters which include applied pressure, pressing time , moisture content and heating temperatures. High degree of moisture content effect on oil yield may be traced to dependent of heat treatment reaction of oil seeds on moisture content.

4. CONCLUSIONS

Based on the findings recorded on oil expression from palm kernel using expeller, model equation was developed to effectively predict palm kernel oil yield at any given moisture content, roasting duration and roasting temperature. Among the investigated process parameters "(viz moisture content, roasting duration and temperature)", moisture content is the most significant factor. The lower the moisture content levels of the kernel under study, the higher the oil yield.

6. REFERENCES

Akinoso R. 2006. Effects of moisture content, roasting duration and temperature on yield and quality of palm kernel (*Elaeis guineensis*) and sesame (*sesamum indicum*) oils. Ph.D thesis,University of Ibadan. Nigeria.

Atiku, A, Aviara N. and M. Haque 2004. "Performance evaluation of a bambara groundnut Sheller". Agricultural Engineering : the CIGR Journal of Scientific Research and Development Manuscript PM 04 002 Vol. VI July 2004

Adekola K. A. 1995. Development of equations to predict coconut oil yield. Paper presented at the annual conference of the Nigeria Society of Agricultural Engineers held at the Federal University of Technology, Akure.

Ajibola, O.O.1989. A study of some factors affecting the hydraulic pressing of palm kernel. Journal of Food Science and Technology (India) 26 (4) : 213 – 217

ASAE , 1998. Moisture measurement. Ungrounded grain and seeds. ASAE S352.2 DEC. 97 :551.

Bachman, J.2004. Oil seed processing for small scale producers. NCAT Agriculture Specialist USA. www. attar.org/attra-pub/PDF/ oil seed.pdf. revised May 2004. (14-9-04)

Fasina, O.O and O.O.Ajibola. 1989. Mechanical expression of oil from conophor nut (*Tetracarpidium coconophorum*)". Journal of Agricultural Engineering Research. 44 :275 – 287

Frank, T.O.1998.Vegetable Oils. Bailey's Industrial Oil and Fat Product. John Wiley and Son's Inc. New York. 1 : 19-44

Guderjan M, Top, S. Argersbach A. and A. Knorr 2005. Impact of pulsed electric field treatment on the recovery and quality of plant oil. Journal of Food Engineering 67:3 pp 281-287.

Harper,J.M. and L.A Wanninger 1969. Process modelling and optimisation :- experimental design". Food Technology 23 : 49 – 51

Igbeka, J. C 1982. Simulation of moisture movement during drying of starchy food products-cassava". Journal of Food Technology 17: 27 – 36.

Khan, L. M. and M.A. Hanna 1984. Expression of soybean oil. Transactions of the American Society of Agricultural Engineer 27 :190-194.

Kheiri, M. S .A.1985. Present and prospective development in the palm oil processing industry. Journal of American Oil Chemists Society 62 (2) : 210 – 219.

O' Brien , R.D. 1998. Fats and oils, formulating and processing for applications. Technical Publishing, Company Inc. Lancaster USA 47-180

Olajide, J.O. 2000. Process optimisation and modelling of oil Expression from groundnut and sheanut kernel. Ph. D thesis, University of Ibadan,

Sangha, M., P. Gupta, V. Thapar and S. Verma 2004. Storage studies on plant oils and their methyl esters. Agricultural Engineering International: the CIGR Journal of Scientific Research and Development. Manuscript EE 03 005. Vol. VI December 2004.

Takakura, T. 2002. Food production strategy in East Asia – engineering perspective in the third millennium. Agricultural Engineering International: the CIGR Journal of Scientific Research and Development. Invited overview paper. Presented at special session on agricultural engineering and international development in the third millennium. ASAE Annual International Meeting / CIGR World Congress, July 30 2002. Chicago, IL.U.S.A. Vol. IV September 2002

Timms R.E.,1985. Physical properties of oils and mixture of oils. Journal of American Oil Chemists Society. 62 (2): 241-248