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Short Communication

Influence of Expeller Design Parameters on Free Fatty Acid Content and Colour of Palm Kernel (*Elaeis guineensis*) Oil

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Abstract. In the study of the influence of compressive stress (10, 20, 30 Mpa), feeding rate (50, 100, 150 kg/h) and rotational speed (50, 80, 110 rpm), of the expeller on the quality of expressed palm kernel oil, compressive stress and feeding rate were found to significantly affect palm kernel oil colour at $P < 0.05$. The lowest value of FFA content (1.09%) was produced at 10 Mpa compressive stress; 50 kg/h feeding rate and 110 rpm revolving worm speed. The highest colour intensity recorded was 87%. Optimum processing condition was achieved at compressive stress of 18.3 Mpa, 61.1 kg/h feeding rate and 76.7 rpm revolving worm speed.

Keywords: palm kernel oil, oil expeller design, free fatty acid, colour

Palm kernel oil is used for edible and non-edible purposes. The edible palm kernel oil must satisfy certain quality parameters including non-rancid flavour, low peroxide value, no contaminant, low free fatty acid (FFA) and attractive colour (NIS, 2000). FFA is formed as a result of lipid hydrolysis and has been identified as a major quality parameter since it influences other quality characteristics (Weiss, 2000). FFA results from splitting of the glyceride molecule at the ester linkage with the formation of fatty acids that contributes objectionable odour, flavour and other characteristics. It is an important quality indicator during each stage of fat and oil processing. FFA content, colour and appearance of the crude oil affect the cost of processing, and the quality of the finished product.

Moisture content, roasting duration and roasting temperature significantly influence yield and quality of palm kernel oil (Akinoso and Igbeka, 2007). These parameters are independent of oil expeller. Compressive stress, feeding rate and revolving worm speed are essential in design and production of expeller. These have been reported to be significant on palm kernel oil yield (Akinoso *et al.*, 2009). The objective of this study is to investigate the influence of compressive stress (10, 20, 30 Mpa), feeding rate (50, 100, 150 kg/h) and revolving worm speed (50, 80, 110 rpm) of oil expeller on free fatty acid and colour of palm kernel oil.

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For the study, a 3 x 3 factorial experimental design was used. A *tenera* variety of palm kernel was procured from Nigeria Institute for Oil Palm Research (NIFOR), Benin City, Nigeria. Using ASABE (2008) standard for oil seed, moisture content of the palm kernel was determined to be 5.5% (wb). The oil seed was cleaned manually to remove contaminants such as shell, pebbles and broken kernel. Samples of 5 kg weight each were used for the experiment.

The expeller used was Tite 002 manufactured by Tiny Tech Plant, India, of a rated capacity of 180 kg/h, powered by a 30 kW electric motor with interchangeable speed. Rate of feeding used was 50, 100, and 150 kg/h and compressive stress was established at 10, 20, 30 Mpa. The transducer sensor was placed within the lining bars of the barrel, which relay corresponding internal pressure. Variation of the expeller worm shaft speed of 50, 80 and 110 rpm was achieved by changing the gear switch.

The expressed oil was clarified and analysed for free fatty acid (FFA) and colour change using standard methods (Ca 5a-40) for the FFA content and (Cc 13c-50) for the colour of oils (AOCS, 1994).

For FFA determination, 5 g of oil sample was mixed with 50 mL of hot neutral alcohol and phenolphthalein and titrated with 0.5 N NaOH. Reaction followed as under:

$$C_{17}H_{33}COOH + NaOH = C_{17}H_{35} + COONa + H_2O.... (1)$$

The results were analysed statistically by regression and

ANOVA using SPSS 13.0 package to obtain the relationship between the independent and dependent variables. Mathematical models were developed. The optimum process parameters for oil expression were determined using simplex method of linear programming as reported by Belegundu and Chandrupatla (2003). A computer programme was employed to optimise interaction between the developed model equations. In optimising free fatty acid was minimised while colour was kept at acceptable level. To validate the optimal parameters, palm kernels were expressed at these conditions. The results were compared with predicted values.

The highest value of FFA (2.7 %) was recorded at 10 MPa compressive stress, 100 kg/h feeding rate and 50 rpm rotational speed while the lowest value (1.09 %) was obtained at 10 MPa compressive stress, 50 kg/h feeding and 110 rpm speed (Table 1). According to Nigeria Industrial Standard, the maximum permissible FFA content in virgin palm kernel oil is 2.0% (NIS, 2000). Out of the 27 treatments, 55.6 % satisfied the recommended quality standard.

The result of regression analysis and ANOVA revealed that the FFA content of the expressed oil didn't correlate well with the predictors: (constant), compressive stress (P, MPa), feeding rate (FR, kg/h), speed (S, rpm), although a relationship exists. This was evident in the very low value of R^2 (0.126). It was discovered that none of the predictors have significant effect on the FFA content at $P < 0.05$. This was also evident in the regression functional relationship with very low coefficients for all the predictors or the independent variables, which is given as equation 2.

$$FFA = 2.5 + 0.37 \times 10^{3} P + 1.17 \times 10^{3} FR - 1.82 \times 10^{2} S \quad ...(2)$$

Where FFA is the free fatty acid, P is the compressive stress, FR is the feeding rate and S is the rotational speed. Non-significant effects of the predictors on FFA contents of expressed palm kernel oil were equally recorded from the analysis of the independent effect of the three variables. Correlation coefficients (R) of 0.04, -0.06 and -0.34 were obtained for compressive stress, feeding rate and rotational speed respectively. Values of coefficient of determination R^2 were very low, although relationships existed (equations 3-5).

$$FFA = 1.878 + 3.5 \times 10^{-3} P \quad \cdots\cdots (3),\ R^2 = 0.002$$

$$FFA = 1.992 - 6.6 \times 10^{-4} FR \quad \cdots\cdots (4),\ R^2 = 0.004$$

$$FFA = 2.68 - 9.2 \times 10^{-3} S \quad \cdots\cdots (5),\ R^2 = 0.119$$

Contrary to high significant effects of pre-processing parameters (moisture content, roasting duration, roasting temperature and particles size) on palm kernel oil FFA content reported by Akinoso and Igbeka (2007), the studied design parameters (compressive stress, feeding rate and speed) influence was non significant at $P < 0.05$. However, Sivakumaran and Goodrum (1987) reported significant influence on internal pressure and feeding rate on oil expression efficiency using small screw expeller. Therefore, effects of the studied parameters on functionality of an expeller cannot be neglected. O'Brien (2008) attributed abnormal high FFA levels in crude vegetable oils to poor seed handling, field damage of seeds and improper storage. Seed enzyme lipase is activated by moisture and hydrolysis is initiated, which increases the FFA content. Palm kernel used for the experiment was properly cleaned, sorted and used within 24 h of harvest, this may account for the observed behaviour. Also, initial moisture content of the kernel was moderate.

The colour ratings of the expressed palm kernel oil are shown in Table 1. The highest colour intensity of 87 % was achieved at 30 MPa compressive stress, 150 kg/h feeding rate and 110 rpm speed while 20 MPa compressive stress, 50 kg/h feeding rate and 50 rpm speed produced the least colour intensity of50%. Recommended range as industrial standard for palm kernel oil colour is 45 – 80% (NIS, 1992). Out of the 27 treatments, 88.9 % fall within the range. Vegetable oil colour was due to the presence of carotene and chlorophyll pigments. It was known that crude oils could have unexpectedly high pigmentation caused by field damage, improper storage or faulty handling during crushing. Since the samples were subjected to same pre-treatment, none of the aforementioned factors might have influenced the observed colour variation. As reflected in the correlations analysis of the obtained data on colour and ANOVA, compressive stress (P, MPa), feeding rate (FR, kg/h), correlated positively to the colour while rotational speed (S, rpm) correlated negatively. From the analysis, it was discovered that only compressive stress and feeding rate are significant at $P<0.05$. This is also evident in the regression functional relationship given as equation 6. Coefficient of determination R_2 of the equation is 0.53, an indication that the model fits with the data.

$$Colour\ (CO) = 56.89 + 0.16\ P + 0.14FR - 0.03S \quad .... (6)$$

Colour fixation in vegetable oil was reported by Akinoso *et al.* (2006) to be due to oxidation aided by high temperature. Thus, recorded significant effects of compressive stress and feeding rate on palm kernel colour may be traced to fluctuation in temperature of expeller barrel and worm which was noticed with the variation of these parameters. Equations 7-9 show

Table 1. Palm kernel FFA and colour as influenced by the technological parameters

Treatment	Compressive stress (Mpa)	Feeding rate (kg/h)	Speed (rpm)	*Free fatty acid (%)	*Colour (%)
1	10	50	50	2.13 ± 0.91	71 ± 16.3
2	10	100	50	2.70 ± 1.11	75 ± 14.7
3	10	150	50	2.01 ± 0.36	83 ± 18. 7
4	20	50	50	1.77 ± 0.98	50 ± 11.9
5	20	100	50	2.13 ± 0.85	76 ± 9.07
6	20	150	50	1.42 ± 0.11	80 ± 22.0
7	30	50	50	1.77 ± 0.09	60 ± 13.6
8	30	100	50	2.13 ± 1.64	76 ± 26.0
9	30	150	50	2.50 ± 0.17	84 ± 13.7
10	10	50	80	2.13 ± 0.84	65 ± 20.0
11	10	100	80	1.42 ± 1.02	75 ± 13.0
12	10	150	80	2.13 ± 1.47	75 ± 13.9
13	20	50	80	1.71 ± 1.17	75 ± 14.4
14	20	100	80	2.30 ± 0.81	64 ± 11.2
15	20	150	80	1.73 ± 0.77	79 ± 29.0
16	30	50	80	1.77 ± 1.13	67 ± 11.3
17	30	100	80	1.73 ± 0.75	67 ± 14.6
18	30	150	80	2.10 ± 1.93	79 ± 27.0
19	10	50	110	1.09 ± 0.07	59 ± 22.0
20	10	100	110	1.70 ± 1.14	68 ± 15.1
21	10	150	110	2.15 ± 2.01	67 ± 9.8
22	20	50	110	1.42 ± 1.13	61 ± 12.4
23	20	100	110	1.42 ± 1.01	72 ± 27.0
24	20	150	110	1.77 ± 0.99	77 ± 23.1
25	30	50	110	2.48 ± 1.21	73 ± 21.0
26	30	100	110	1.77 ± 0.68	73 ± 16.8
27	30	150	110	1.42 ± 1.07	87 ± 26.7

* = mean of three replicates.

independent effect of the three variables on palm kernel oil colour as obtained from the regression analysis. As revealed, only feeding rate is significant at $P < 0.05$ with correlation coefficient (R) of 0.71. Compressive stress and speed coefficients (R) are 0.15 and 0.1, respectively, which show that variation in compressive stress without accompany variation in feeding rate and speed will not significantly change the colour of palm kernel oil expressed using the expeller while the influence of feeding rate is independent of other factors. Similarly, Ajibola *et al.* (1993) also reported non-influence of pressure on colour of sesame seed oil expressed using hydraulic press.

$$CO = 68.67 + 0.16\,P \quad \text{.............. (7)}, \; R^2 = 0.02$$
$$CO = 57.33 + 0.14\,FR \quad \text{............... (8)}, \; R^2 = 0.5$$
$$CO = 74.44 - 3.33\times10^{-2}\,S \quad \text{........... (9)}, \; R^2 = 0.01$$

Optimum processing condition was achieved at compressive stress of 18.3 Mpa, 61.1 kg/h feeding rate and 76.7 rpm revolving worm speed. This combination produced 1.24% FFA content and 76.9% colour rating which are within acceptable standard limits. The percentage errors recorded are 2.7 and 4.1% for FFA content and colour, respectively. At 5 % level of significance, all the optima parameters as predicted are permissible and thus appropriate to be applied.

Relationships existed between the compressive stress, feeding rate and rotation speed of the vegetable oil expeller FFA content and colour of the expressed palm kernel oil. Only colour was significantly influenced by compressive stress and feeding rate at $P < 0.05$. Quality of virgin palm kernel oil *viz:* FFA content and colour dependent on the studied parameters is marginal. The developed obtain model can be used to predict influence of studied technological parameters on FFA content and colour of expressed palm kernel oil.

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