Effect of some kernel factors on palm kernel oil extraction using a screw press

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Abstract: Several factors are known to affect mechanical oil extraction from oilseeds. In this study, the influence of kernel moisture content (KMC), kernel heating temperature (KHT), kernel heating duration (KHD) and kernel particle size (KPS) on palm kernel oil (PKO) yield by a mixed variety of oil-palm kernels using a locally fabricated screw press was investigated. The one-factor-at-a-time (OFAT) experimental approach was employed. Design-Expert 8P (Version 8.0.6) software was used for statistical analysis of data. Within the range of values of variables studied, the results showed that at the 5% significance level only kernel size significantly affected PKO yield. Thus, KPS is a critical factor in PKO extraction using the screw press. Oil-palm kernels should not be crushed when using a screw press designed for whole kernels, because, doing so will most likely result to poor oil yield.

Keywords: kernel factors, palm kernel oil, screw press, effects, oil-palm, oil extraction

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1 Introduction

The oil-palm kernel is well known as a source of palm kernel oil (PKO), which is edible and industrial oil; and palm kernel cake (PKC) is a good component of livestock feeds. Palm kernel oil as food is a source of concentrated energy; vegetable oils generally enhance palatability of other foods. The oil could be used as a lubricant and an emulsifier. It is an ingredient in paint making as a drying base, and in the manufacture of candles. Upon hydrogenation, the oil can be used to produce margarine. The oil is an important constituent in the manufacture of shorteners and confectioneries. PKO is extensively used to make soap. In fact, lauric acid from the oil when boiled with alkali is used to make soap of the best quality due to its superior lathering characteristics. The oil is used to produce glycerol as a by-product of the soap making process. PKO is also useful in the production of cosmetics (VON, 1987; Okpaluba, 1988; Ekwulugo, 2001; Akubuo and Eje, 2002; Obetta, 2003; Gbadamosi, 2006).

Expression of oil from oilseeds is an important operation in post-harvest technology. The factors affecting the mechanical oil expression from oilseeds and nuts have been studied extensively. These factors include moisture content, heating temperature, heating time, applied pressure, duration of pressing, particle size (Fasina and Ajibola, 1989; Ajibola et al., 1990; Adeeko and Ajibola, 1990; Hamzat and Clarke, 1993; Singh and Bargale, 1990; Akinoso et al., 2006). Among these researchers, only Akinoso et al. (2006) and Singh and Bargale (1990) used screw press. Others used hydraulic piston press. Only Akinoso et al. (2006) worked on oil-palm kernels; but the kernel particle size was not

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considered.

The objective of this study was, therefore, to investigate (using one-factor-at-a-time (OFAT) experimental approach) the influence of kernel moisture content (KMC), kernel particle size (KPS), kernel heating temperature (KHT), and kernel heating duration (KHD) on PKO yield, using a locally fabricated screw (expeller) press (Ezeoha, 2016).

2 Methodology

Two separate batches of palm kernels (30 kg each) were purchased at Orie Orba Market in Nsukka, Enugu, Nigeria. The first batch was used to investigate the effects of kernel moisture content and kernel heating temperature on PKO yield. The second batch was used to investigate the effects of kernel particle size and kernel heating duration on PKO yield. On arrival, the batches were sorted to remove un-cracked and partially-cracked nuts and unwholesome kernels. The kernels were sieved to remove dust, debris, and other foreign materials. The initial moisture contents of the kernels were determined in accordance with ASAE S410.2 (2010). After that, the kernels were conditioned to the particular investigation requirements as outlined in sections 2.1 to 2.4. The kernels were finally put into randomly-numbered and labeled containers (3-litre buckets) ready for processing in the screw press.

Palm kernel screw press (MS – 100) fabricated by Magnus (Nigeria) was used for the oil extraction. The press has a capacity of about 101.7 kg h^{-1} at a speed of 56 rpm, powered by a 45 kW, 3 phase electric motor. The screw press had a test run for about 2 min before loading and processing the conditioned samples. The expressed oil per sample was collected in a 3-litre transparent plastic bucket via a muslin cloth cover. The muslin cloth was used to filter the oil being collected. The collected oil was clarified by allowing it to stand for 48 h. The volume of clean oil was measured with a graduated transparent plastic 500 mL beaker.

2.1 Effect of kernel moisture content on PKO yield

The initial moisture content of the kernel batch used for this investigation was 5.0% w.b. The kernels were conditioned to four levels of moisture content (3%, 5%, 7%, and 10% w.b.), with five replicates each giving a total of 20 samples of 500 g per sample. First, a given quantity of the kernels at 5.0% moisture content (w.b.) was determined using Equation 1 and then dried down to 3.0% w.b. Thereafter, other quantities (2.4 kg each) were conditioned in two separate plastic buckets to moisture contents of 7.0% and 10% w.b., respectively, by mixing with different amounts of distilled water calculated from Equation 2 (Coskun et al., 2005; Ozumba and Obiakor, 2011). The wetted samples in the separate plastic buckets were sealed and kept at 5°C in a refrigerator for one week to achieve uniform moisture distribution. All samples were then heated at 130°C for 10 min in an oven before being processed in the screw press.

$$M_f = M_0 \times \frac{100-MC_i}{100-MC_f} \quad \text{(IRRI, 2015)} \qquad (1)$$

Where:

M_f = desired mass of sample at MC_f (g)

M_0 = original mass of sample (g)

MC_i = original moisture content of sample (%)

MC_f = desired moisture content of sample (%)

$$Q = \frac{A(b-a)}{(100-b)} \qquad (2)$$

Where:

Q = quantity of distilled water to be mixed with the kernel sample (g)

A = initial mass of the kernel sample (g)

a = initial moisture content of the kernel sample (% w.b.)

b = desired moisture content of the kernel sample (% w.b.)

2.2 Effect of kernel heating temperature on PKO yield

The kernels conditioned from 5% to 3% m.c. (w.b.) were heated at 4 levels of heating temperature (30°C, 50°C, 90°C, and 130°C) for 10 min each with five replications each, giving a total of 20 samples of 500 g per sample. All the samples were completely randomized and processed in the screw press.

2.3 Effect of heating duration on PKO yield

The initial moisture content of the kernel batch used for this investigation was 6.6% (w.b.). These kernels were heated at 80°C at four levels of heating duration (5, 10, 15, and 20 min) with five replications at each level, giving a total of 20 samples of 500 g per sample. The experimental runs were completely randomized.

2.4 Effect of kernel particle size on PKO yield

The samples, initially at moisture content (wb) of 6.6%, were heated at 80°C for 10 min. The investigation was done at three levels of average kernel particle size (3, 8, and 11 mm). Three replications per factor level were employed giving a total of nine samples of 1 kg per sample. The experimental runs were completely randomized.

3 Results and discussion

3.1 Effect of kernel moisture content on PKO yield

The Analysis of Variance (ANOVA) for this experiment showed that the moisture content factor had a p-value of 0.3110 indicating that the contribution of moisture content (within the range of 3% to 10% w.b.) to changes in PKO yield for samples heated at 130°C for 10 min was not significant at 5% significance level ($p > 0.05$). The treatment mean yield was 179.00 ± 19.20 mL/500 g-kernels. The plot of PKO yield versus kernel moisture content is shown in Figure 1. This figure shows that kernels at 5% moisture content (w.b.) gave the highest mean PKO yield of 190.00 ± 8.59 mL/500 g-kernels. Comparison of treatment means shows that the differences in mean yields for 5%, 7%, and 10% w.b., kernel samples were not significant, but was significant for 3% and 5% w.b., samples. The figure equally shows that the decrease in KMC produced increments in PKO yield except for KMC of 3% w.b., where oil loss occurred in the heating vessel before the actual oil extraction in the screw press.

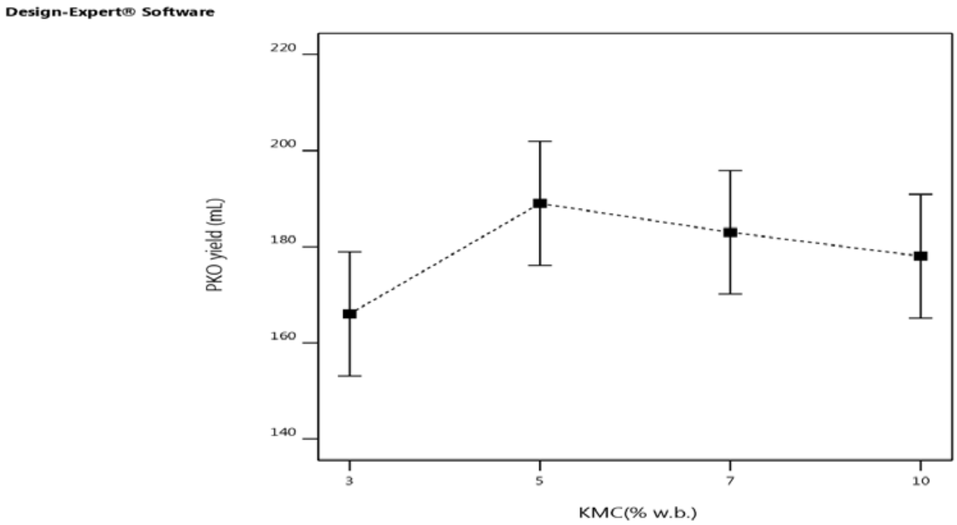

Figure 1 Graph of PKO yield against kernel moisture content (KMC)

3.2 Effect of kernel heating temperature on PKO yield

The ANOVA for this experiment showed a p-value of 0.2368 for heating temperatures (30°C to 130°C range) indicating non-significant contribution ($p > 0.05$) to changes in PKO yield for whole kernel samples at 3% m.c. (w.b.) and 10 min heating duration at 5% significance level. The treatment's mean PKO yield was 164.00 ± 12.30 mL/500 g-kernels. Figure 2 shows that 50°C, heating temperature gave a maximum mean PKO yield of 169 ± 5.5 mL/500 g-kernels for whole kernel samples.

The comparison of means indicates that the differences in mean yields at 50°C, 90°C, and 130°C were not significant. However, significant differences existed between the mean yield at 30°C and yields at 50°C, 90°C, and 130°C indicating that kernel heating at temperatures above ambient (27°C-30°C) was important for higher PKO yield. Figure 2 equally shows that the increase in KHT produced an unsteady rise in PKO yields, except for KHT increase from 30°C to 50°C which produced a clear rise.

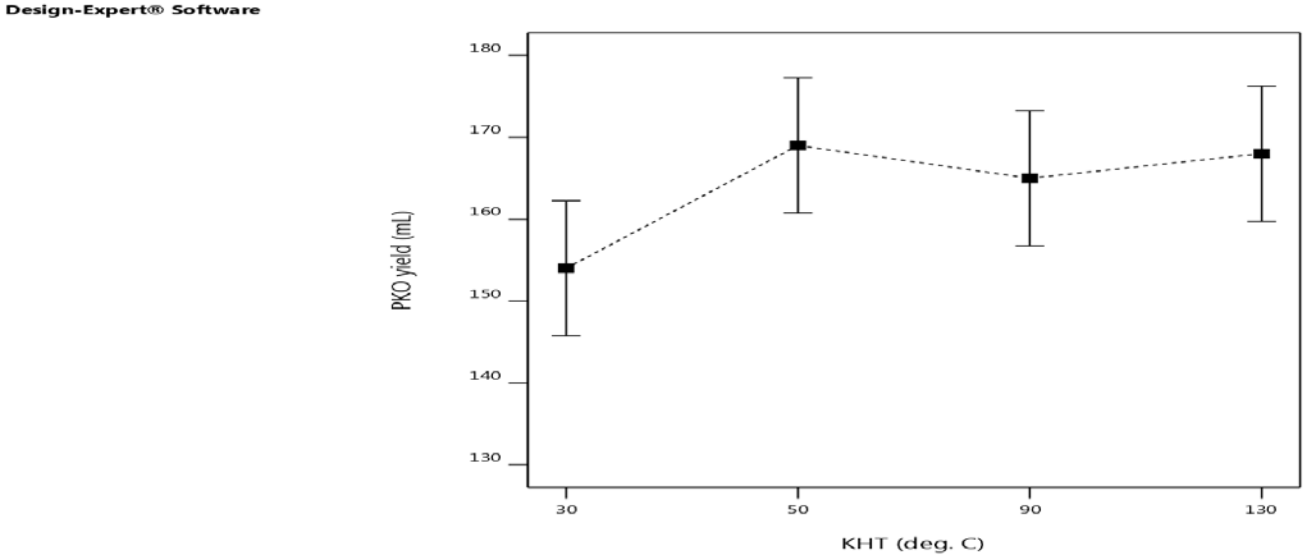

Figure 2 Graph of PKO yield against kernel heating temperature (KHT)

3.3 Effect of kernel heating duration on PKO yield

The ANOVA for this experiment showed a p-value of 0.2273 for the heating duration, indicating non-significant contribution to variations in PKO yields at 5% significance level within the range (5–20 min) studied. The mean PKO yield for the whole kernels at 6.6% moisture content (w.b.), heated at 80°C for durations of 5, 10, 15, and 20 min was 167 ± 18.1 mL. Figure 3 shows that 10 min heating duration gave a maximum mean yield of 179 ± 8.12 mL. The differences in mean yields for 5, 10, 15, and 20 min heating durations were not significant at 5% significance level. Figure 3 shows that the increase in KHD produced an unsteady rise in PKO yields, except for the initial increase from 5 min to 10 min which shows a clear rise in yield.

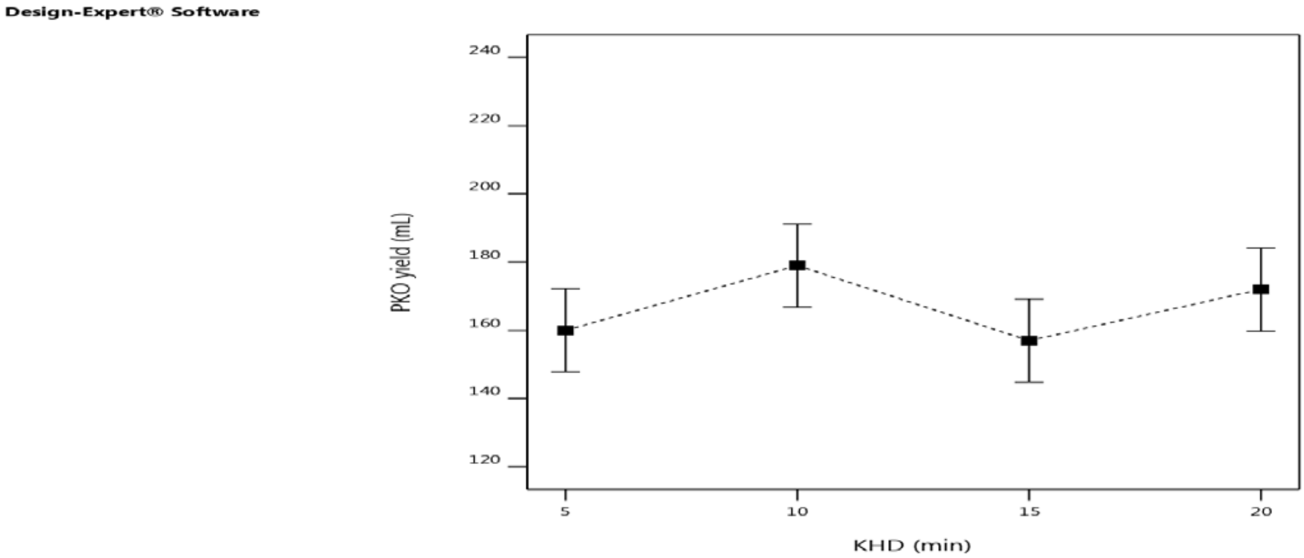

Figure 3 Graph of mean PKO yield against kernel heating duration (KHD)

3.4 Effect of kernel particle size on PKO yield

The ANOVA for this experiment showed that kernel particle size had a p-value of 0.0002 indicating that the factor makes highly significant ($p< 0.05$) contribution to changes in PKO yield at 5% significance level, especially for kernels at 6.6% moisture content (w.b.), heated at 80°C for 10 min. This shows that crushing of kernels was unfavourable for PKO yield using the screw press. Whole soybean seeds yielded more oil than soy-split samples (Singh and Bargale, 1990). The treatment's mean PKO yield was 304.4 ± 28.43 mL/1000 g-kernels.

Figure 4 shows that the 11 mm sized kernels gave the maximum mean PKO yield of 393.3 ± 16.44 mL/1000 g-kernels, followed by 8 mm sized (broken) kernels with

340 ± 16.44 mL. The mean PKO yield of 3 mm sized kernels was significantly different and lower than the mean PKO yields of 8 mm and 11 mm sizes. Figure 4 clearly shows that the increase in KPS produced a steady rise in PKO yields.

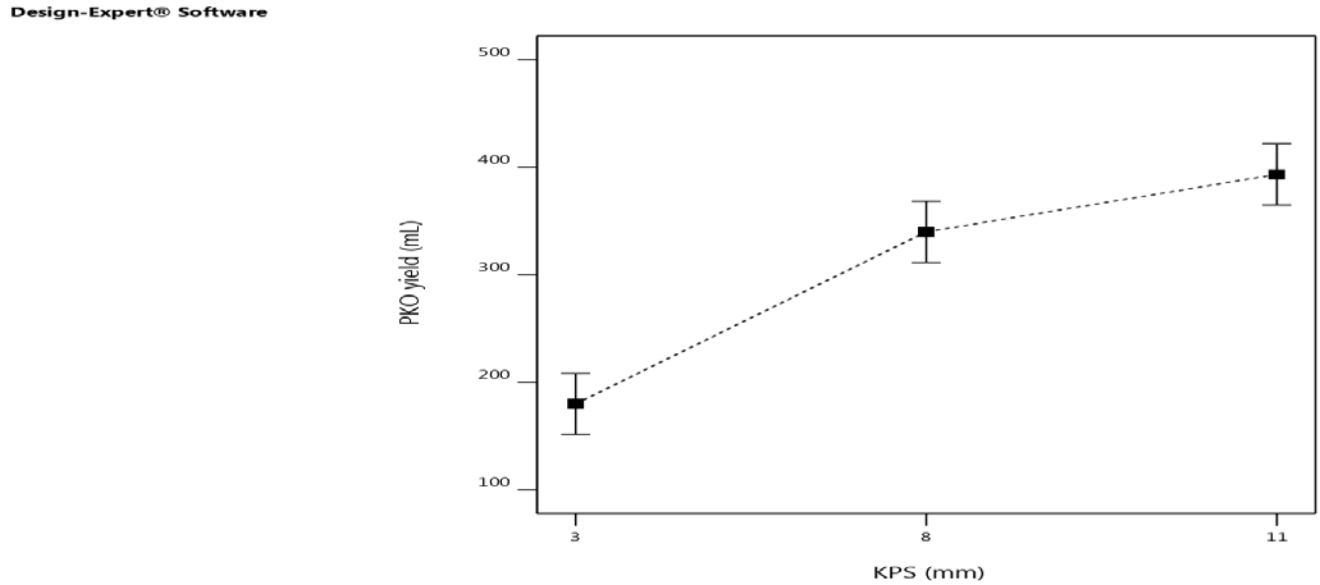

Figure 4 Graph of PKO yield against kernel particle size (KPS)

3.5 Summary of results and discussion

Table 1 shows the summary of the effect of kernel factors studied on PKO yield as displayed in sections 3.1 to 3.4. The kernel conditions for maximum mean PKO yield of 197 mL/500 g-kernels (mixed variety) were 6.6% moisture content (w.b.), 80°C, heating temperature, 10 min heating duration, and particle size of 11 mm and above. Akinoso et al. (2006) got a maximum PKO yield of 260 mL/500 g-sample of Tenera variety at kernel moisture content of 4.5% (w.b.), 130°C, and 5 min heating duration.

Table 1 Summary of effect of kernel factors on PKO yield

S/No.	Kernel factors/PKO yield	OFAT Experiment No.			
		2.1	2.2	2.3	2.4
1	KMC (%w.b.)	5	6.6	3	6.6
2	KHT (°C)	130	80	50	80
3	KHD (min)	10	10	10	10
4	KPS (mm)	11	11	11	11
5	Max PKO yield (mL*)	220	180	180	205
6	Max average PKO yield (mL*)	190	179	179	197

Note: mL* = mL/500 g-kernels

4 Conclusions and recommendation

The OFAT approach was used to investigate the effect of kernel moisture content, heating temperature, particle size, and heating duration on the oil yield, and the results were already discussed. In order to achieve maximum yield of PKO when the MS – 100 screw press is used to extract oil from palm kernels, the following conclusions and recommendation are presented based on the results of this study:

(1) The best moisture content for PKO yield for whole oil-palm kernels (mixed variety) heated at 130°C for 10 min heating duration was 5% (w.b.). But, since the differences in mean PKO yields were not significant for the range (3% – 10% w.b.) of moisture contents studied, it is uneconomical to dry kernels from above 5% moisture content (w.b.) down to 5% w.b. or below. They should be processed if the moisture content is within the range of 5% to 10% w.b. after heating at 130°C for 10 min.

(2) The best whole kernel heating temperature for 10 min heating duration for oil-palm kernels at 3% moisture content (w.b.) was 50°C. But, since the difference in mean PKO yields were not significant for 50°C, 90°C, and 130°C except for the ambient (30°C), it is more economical to heat at the lowest temperature that is higher than the ambient (i.e. 50°C).

(3) The best kernel size for oil-palm kernels at 6.6% (w.b.) moisture content, heated at 80°C for 10 min duration was 11 mm. This suggests that whole kernels and large-sized broken kernels yield more PKO than crushed kernel particle sizes. Oil-palm kernel particle size is critical for the MS-100 Screw Press. Therefore, oil-palm kernels should not be crushed before processing

with this screw press. Whole kernels yield more oil and cause no hiccups in the operation of the screw press.

(4) The best heating duration for kernels at 6.6% moisture content (w.b.), employing 80^{o}C heating temperature was 10 min. Since the difference in mean PKO yields was actually not significant for 5, 10, 15, and 20 min heating durations, the shortest duration that gives the maximum yield (10 min in this case) is best, economically.

(5) The insignificance of the factors studied (except kernel particle size) and the negative values of Predicted R-Squared are pointers to the possible interaction of factors. Therefore, further experimental investigations are recommended.

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