

Pre-Cleaning System for Premium Palm Kernel Cake Production

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ABSTRACT

Palm kernel cake (PKC) that contains more than 75% cell wall components, constituting mannose (35.2%), xylose (2.6%), arabinose (1.1%), galactose (9.0%), lignin (15.1%), and ash (5.0%), is extensively employed as ingredient in feed rations for cattles, buffaloes and dairy cows. A palm kernel pre-cleaning system developed with three-stage winnowing columns to remove fibre and shell before pressing, had successfully produced premium PKC, also known as PURAFEX. It contained less than 8% shell, less than 12% crude fibre, and more than 16% crude protein. It is thus suitable to be used as feed ingredient for monogastric and ruminants.

Keywords: Animal feeds, palm kernel cake, pre-cleaning winnowing.

INTRODUCTION

Palm kernel cake (PKC) is generated after the extraction of palm kernel oil using mechanical screw press at the palm kernel crushing plant (KCP). In Malaysia, about 2.5 million PKCs are generated annually by 43 KCPs (MPOB, 2022), of which 98% of the PKCs were exported for ruminant feed (Figure 1). This makes Malaysia the world's largest producer and exporter of PKC which assures its supply and availability as a key ingredient in livestock feed.

PKC is a nutritious by-product of KCP with approximately 4153 Mcal kg⁻¹ gross calories, 14%–18% crude protein (CP), 3%–9% oil and various minerals as shown in Table 1 (Azizi *et al.*, 2021). It also contains more than 18% fibrous material comprising

mainly *mannan* or also known as insoluble mannose-based polysaccharides, which are indigestible by monogastric animals such as poultry and swine. Currently, PKC is widely used as major ingredient in ruminant feed (Chong *et al.*, 2008) such as cattle in the European Union (EU), New Zealand, and South Korea. However, its price is considerably low.

TABLE 1. MINERAL CONTENT OF PALM KERNEL CAKE

Mineral	Amount
Calcium (Ca)	0.27%
Phosphorus (P)	0.46%
Magnesium (Mg)	0.11%
Copper (Cu)	25.52 ppm
Zinc (Zn)	53.91 ppm
Manganese (Mn)	259.00 ppm

Malaysia imports corn and protein supplements, mainly soybean to meet the demand of the poultry industry. The escalating cost of conventional feedstuff has triggered the need to optimise the use of available local feedstuff (Hutagalung, 1980) as many local farming enterprises are no longer profitable. Figure 2 depicts the price comparison between PKC, corn and soy meal in 2021 (MPOB, 2022; Indexmundi, 2022). The prices of PKC ranged from RM588.00 to RM742.50. However, the prices of corn and soy meal were higher than PKC, which were between RM1270.00 to RM1500.00 and RM2150.00 to RM2500.00, respectively. Therefore, the quality of PKC needs to be further enhanced, particularly by reducing the fiber and shell content to below 12% and 8%, respectively, for use as a cheaper alternative feed raw material.

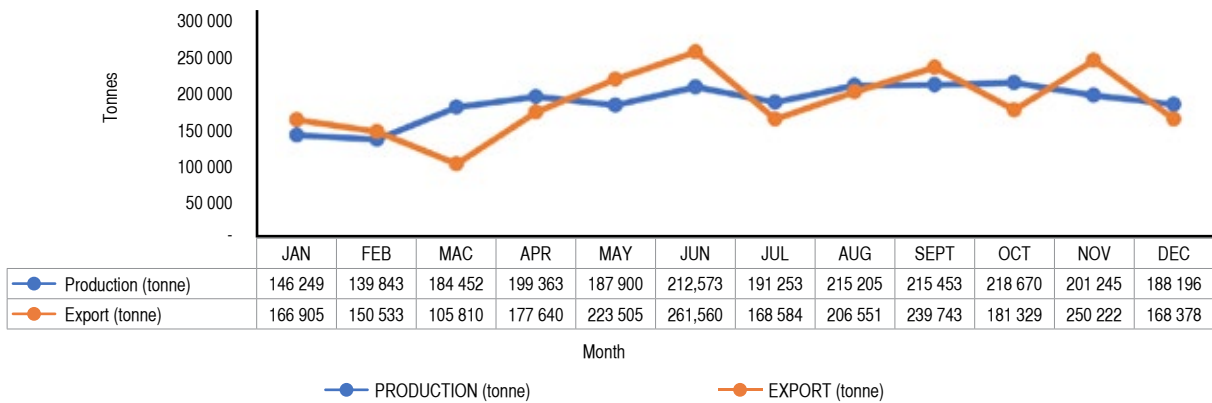


Figure 1. Production and export of palm kernel cake in 2021.

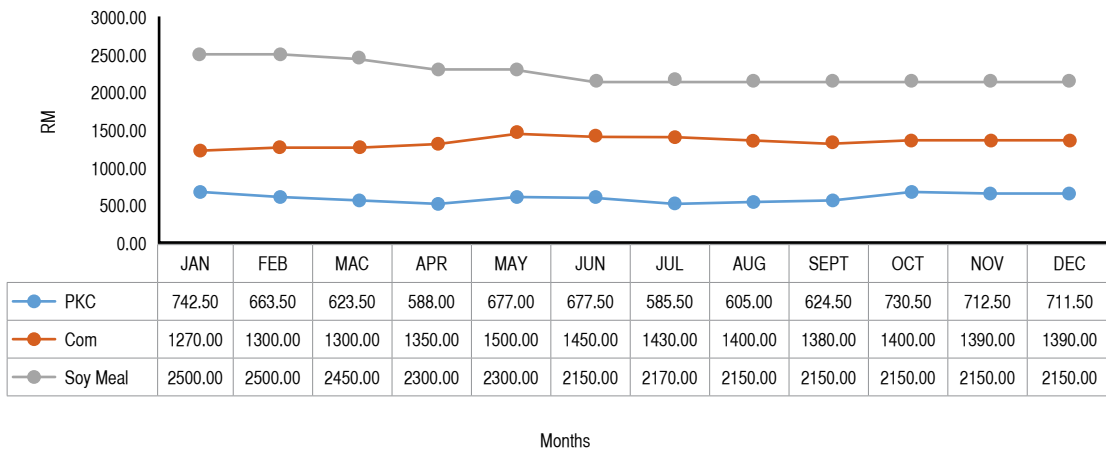


Figure 2. Price comparison between PKC, corn and soy meal commonly used as animal feed ingredient in 2021.

Enzymatic depolymerisation can be used to reduce the fibrous content in PKC and releases digestible sugars in poultry metabolism. Although the process is expensive with unfavorable yield, it demonstrates that specific enzyme supplements can efficiently improve nutrient digestibility and breakdown of mannans (Kompang, 1993; Eustace and Bina, 2005; Saenphoom *et al.*, 2011).

Shell and dirt content is a crucial quality parameter for palm kernels, which measures impurities and foreign matters (Nordin *et al.*, 2005). Palm kernel consignment delivered to the KCP must contain less than 6% shell and dirt according to the specifications of Malayan Edible Oil Manufacturers' Association (MEOMA). Inconsistency in the quality of palm kernels sold and delivered to KCP has

been identified as the main factor compromising the PKC's quality.

A survey conducted by MPOB (Rohaya and Osman, 2002) indicated that the shell and dirt content in kernels delivered to KCP ranged from 6% to as high as 11%. This has contributed to the high percentage of dirt and shell content ranging from 12% to 15% in PKC produced by KCP. If the shell content exceeds 10%, it will induce low crude palm kernel oil (CPKO) yield, thus compromising the PKC's feed value and accelerating the machinery wear and tear (Rohaya and Osman, 2002). Variation in sizes, irregular shapes and similarity in of shells and kernels density made it difficult to eliminate the shells in the kernels (Roslan *et al.*, 2015). Thus, it is desirable to improve the palm kernel quality.

DETERMINATION OF DIRT AND SHELL CONTENT IN PALM KERNEL DELIVERED TO KCP

The determination of dirt and shell content in terms of shell fragment sizes, and half-cracked or whole nuts was carried out for kernel consignments received from 21 palm oil mills owned by Sime Darby group (Figure 3). About 2 kg palm kernel (PK) was sampled from the lorries of different mills.

The kernel samples were grouped as whole nuts (W_1), half-cracked nuts (W_2), loose shells and debris (W_3) (Figure 4) and stones (W_4). Before weighing, whole nuts (W_1) and half-cracked nuts (W_2) were carefully cracked and the shells separately weighed (Rohaya *et al.*, 2021). Equations (1) - (5) were used to compute the total dirt and shell content .

$$W_1(\%) = \frac{\text{weight of shell cracked from whole nut}}{\text{weight of PK}} \times 100\% \quad (1)$$

$$W_2(\%) = \frac{\text{weight of shell from half-cracked nut}}{\text{weight of PK}} \times 100\% \quad (2)$$

$$W_3(\%) = \frac{\text{weight of loose shell and debris}}{\text{weight of PK}} \times 100\% \quad (3)$$

$$W_4(\%) = \frac{\text{weight of stone}}{\text{weight of PK}} \times 100\% \quad (4)$$

$$\text{Total dirt and shell content (\%)} = W_1 + W_2 + W_3 + W_4 \quad (5)$$

Figure 5 illustrates the range of dirt and shell content in palm kernel consignments obtained from 21 mills over two months. The dirt and shell content in palm kernels varied from 3.5% to 5.2%. However, the palm kernels delivered from most of the mills recorded dirt and shell content of below 5.0%, which met the MEOMA specification (<6.0%).



Figure 3. Palm kernel delivered to the kernel crushing plant.



Whole nut

Half-cracked nuts

Big shell

Small shell

Figure 4. Shell content in palm kernel consignments.

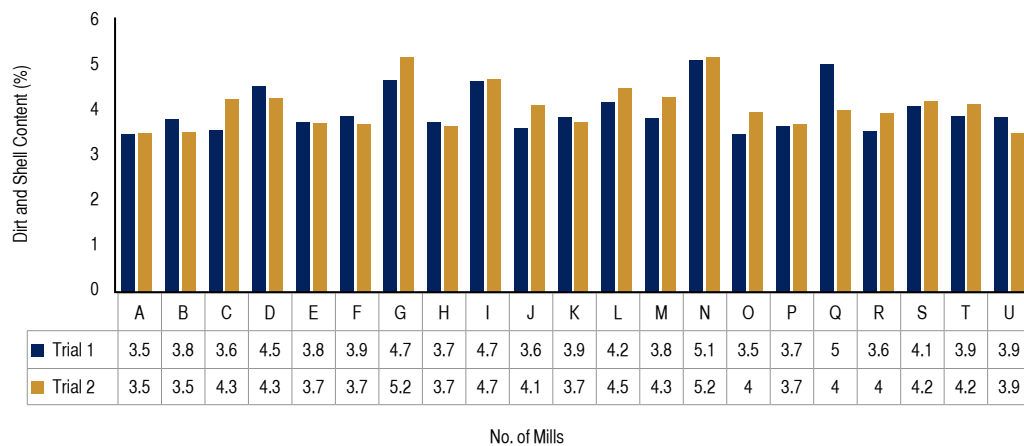


Figure 5. Dirt and shell content in palm kernels from 21 mills for two months.

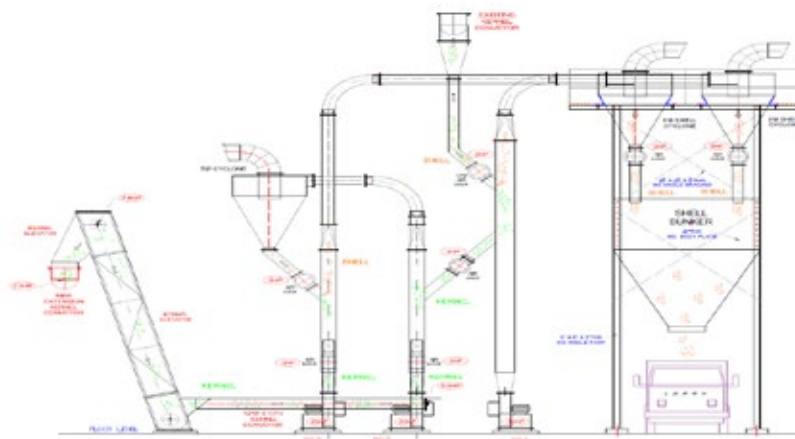


Figure 6. Schematic diagram of palm kernel pre-cleaning winnowing system.

PALM KERNEL PRE-CLEANING SYSTEM

The pre-cleaning system was developed in collaboration between MPOB, Hur Far Engineering Works Sdn. Bhd. and Sime Darby Plantation Sdn. Bhd. The dry separation system consisted of three-stage winnowing columns (Figure 6) which served as a shell removal system to reduce fibres and shells in the palm kernel consignments from $\geq 6\%$ to $\leq 4\%$ before pressing.

The pre-cleaning column was designed with different parameters. Instead of using induced draught, it was operated using a forced draught, in which the airflow rate was generated by an electrical blower and regulated via a damper located on the ground or at an elevated level (Figure 7). Conceptually, a forced draught places the system under positive pressure (above atmospheric pressure), thereby consuming less power than induced draught system operating under negative pressure (below

atmospheric pressure). The placement of a fan at the end of the inflow path generates the forced draught system, where by outside air is drawn and forced into the system. The damper throat geometry is effortlessly adjusted on each separating column to suit the different characteristics of the cracked nut mixture, thus enhancing the separation of kernels and shells. Air velocity at each column was optimised by changing the fan speed from the control panel.

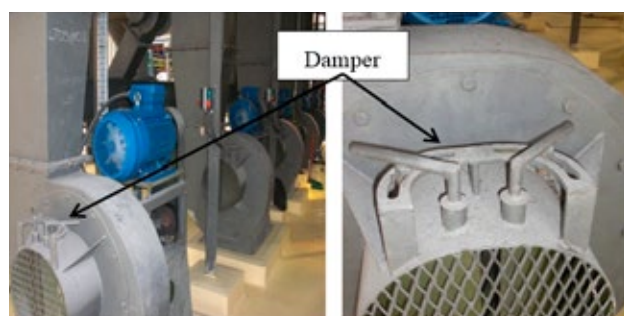


Figure 7. Adjustable damper.

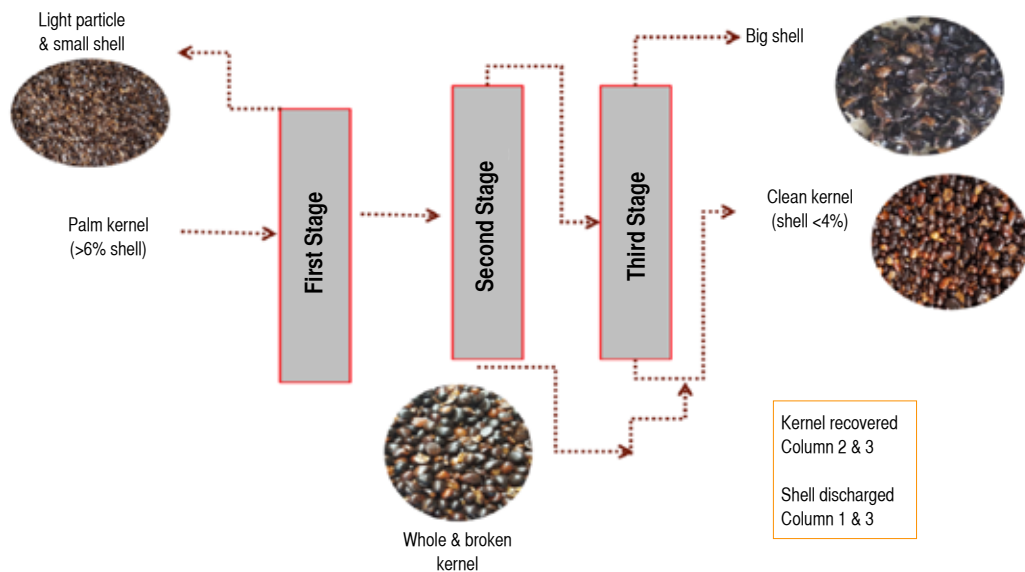


Figure 8. Product separation at each column in pre-cleaning system.

The system consisted of three units of winnowing columns operating with different air velocities (24, 22 and 20 Amp) to ensure maximum shell removal at the targeted parameters. Two distinct shell fragments were released from two different outlets. Fibre and small shell fragments were removed from column 1, whereas large shells were removed from column 3. Whole and broken kernels were recovered from columns 2 and 3 (Figure 8). The kernels, after the pre-cleaning process are utilised as raw material to produce high quality CPKO and PKC with high nutrient values which are highly digestible by monogastric animals.

The separation principle according to the airflow rate, was calculated as follows:

$$V_i v_i \times A_i \quad (1)$$

whereby, V_i is the volumetric airflow rate (m^3/min), v_i is the air velocity (m/min) and A_i is the throat area (m^2), for the respective column i .

PERFORMANCE OF PRE-CLEANING SYSTEM

Figure 9 depicts the performance of the pre-cleaning system in removing of dirt and shell in kernel consignment. The data indicated that the pre-cleaning system was able to reduce the amount of free shells in kernels by 50% when appropriate air velocity was applied at each column.

Before subjected to the pre-cleaning system, the amount of free shells in the kernels varied from 2.0% to 4.0%. However, the amount decreased consistently to below 3.0% after the pre-cleaning system.

The pre-cleaning system also effectively removed free small and big shell fragments. However, large amount of whole nuts and half-cracked nuts were present due to inefficient palm nut cracking performance at the mills, contributing to large amount of dirt and shells in clean kernels (Figure 10). The total amount of shell contributed by free shells, whole nuts and half-cracked nuts was found to fluctuate from 3.4% to 4.4%, slightly exceeding the targeted performance (<4.0%).

The density of these nuts was almost similar to kernels and has high tendency to fall in the palm kernels. Kernel loss was minimal as some of the whole and half-cracked nuts present in the kernel consignments could be removed by the air velocity applied in columns 2 and 3. From the results obtained, it can be deduced that the maximum limit of dirt and shells in palm kernels before undergoing the pre-cleaning system must not exceed 5% so that the target limit of shell in the clean kernels (<4.0%) can be achieved. Shell removal was successfully conducted with a reasonable amount of kernel loss that did not exceed 1.6% (Figure 11). Kernel loss depended on the amount of small broken kernels received by the KCP.

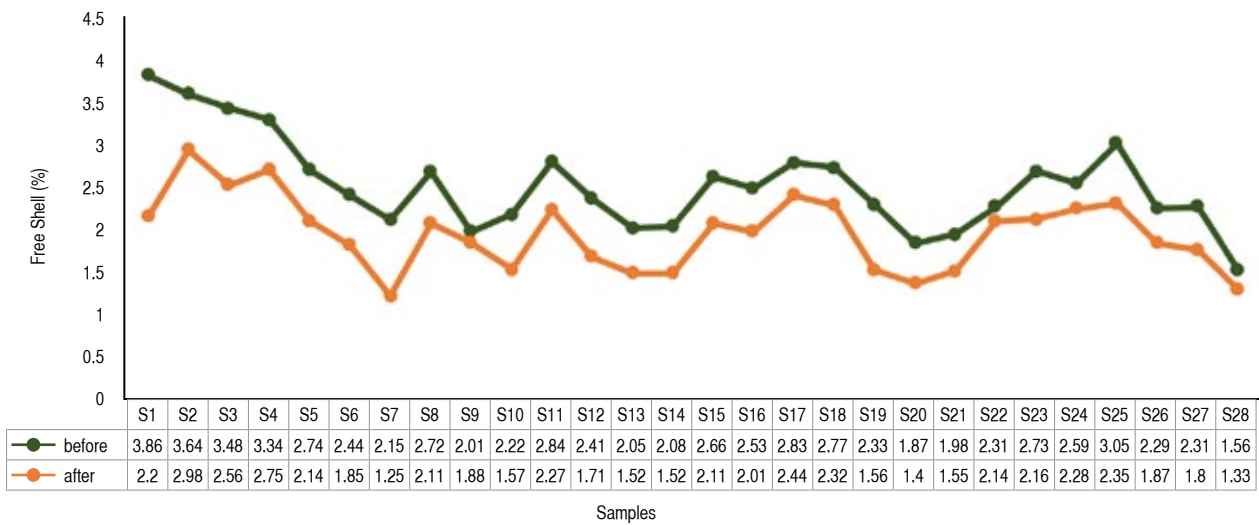


Figure 9. Total dirt and free shells in palm kernels before and after pre-cleaning system.

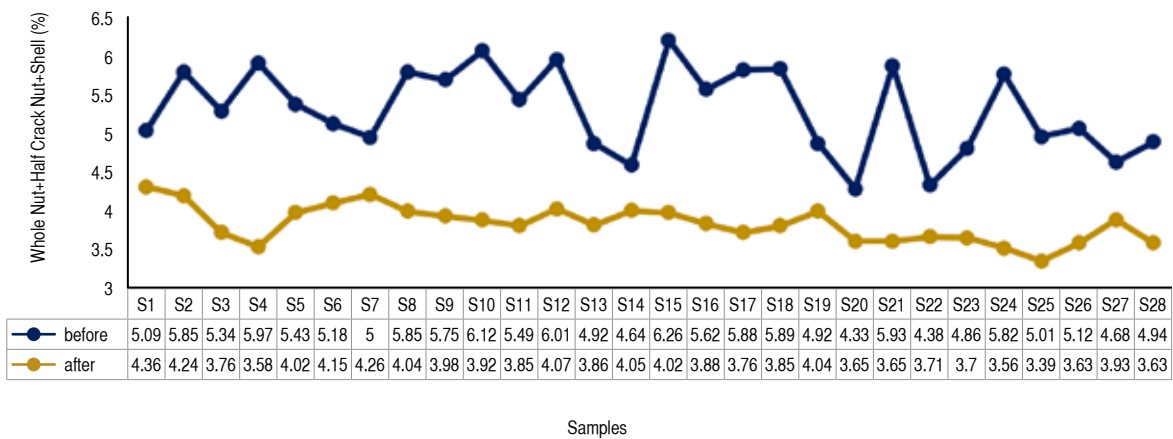


Figure 10. Total dirt and shells in palm kernels before and after pre-cleaning system.



Figure 11. Kernel losses in shells from columns 1 and 3 after segregation.

Figure 12 shows the difference in the composition of palm kernels before and after the pre-cleaning process. The amount of free shells was significantly reduced after the pre-cleaning system compared to half-cracked nuts. The compositions of the products recovered and discharged from the respective columns are illustrated in Figure 13 (Rohaya et al., 2021). Most whole and half-cracked nuts remained in the kernels were recovered from columns 2 and 3.

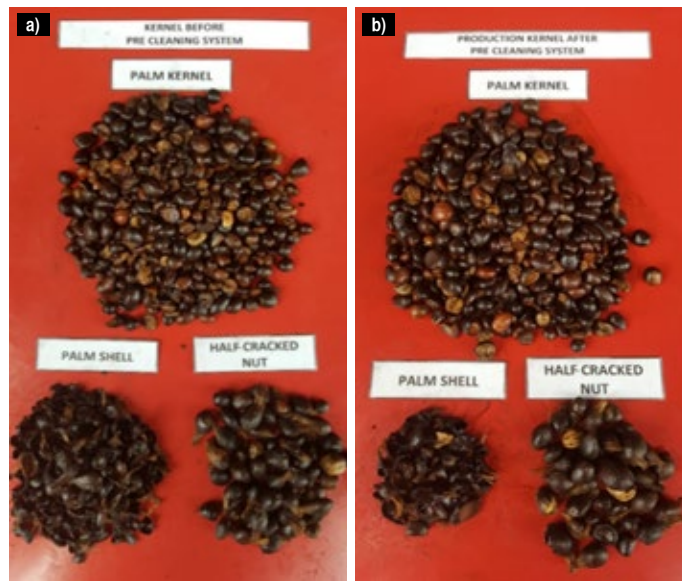


Figure 12. Palm kernel composition: (a) before and (b) after pre-cleaning.



Figure 13. Palm kernels and shells recovered from their respective columns.

PREMIUM PALM KERNEL CAKE PRODUCTION

Premium palm kernel cake known as Palm Based Ultra Refined Animal Feed Expeller (PURAFEX) was commercially produced at Sime Darby KCP, Carey Island, Banting, Selangor since 2017 (Figure 14). PURAFEX was produced from clean palm kernels with low shell (<4%) processed via the pre-cleaning system (Figure 15) for use as feed material. Overall process flow for the commercial production of PURAFEX using the pre-cleaning system is shown in Figure 16.

PURAFEX refers to PKC with lower shell content ($\leq 6\%$) and higher crude protein content ($\geq 16\%$) than commercial PKC (shell content of $\geq 12\%$ and crude protein of 14%). Crude protein content is greatly influenced by the amount of shell, whereby a high shell content will reduce the crude protein content (Rohaya and Osman, 2002). As specified by MEOMA is trade specification for domestic contract (MEOMA, 2000), the minimum level of protein content in PKC is 14% . PURAFEX also contained lower amount of crude fibre ($\leq 12\%$) than commercial PKC ($\geq 18\%$) in align with nutrient requirements for broilers when the PURAFEX inclusion level is below 30% (Rohaya *et al.*, 2021).



Figure 14. Commercial production of premium palm kernel cake in the warehouse of KCP.



Figure 15. Pre-cleaning system installed at the Sime Darby Kernel Crushing Plant, Carey Island, Banting, Selangor.

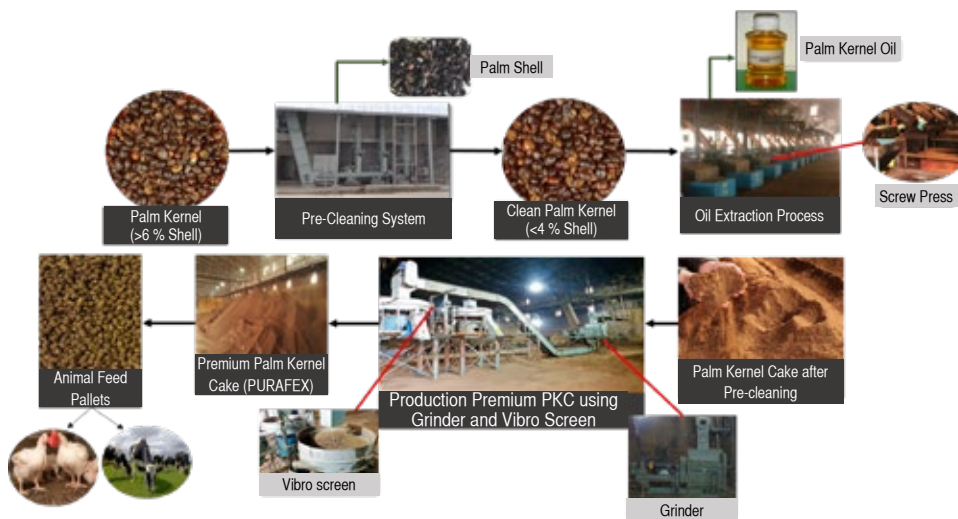


Figure 16. PURAFEX commercial production process flow.

Comparisons between crude protein, crude fibre and shell content for PURAFEX and commercial PKC are illustrated in *Figures 17* until *19*. Determination of crude fibre and crude protein in PURAFEX sample was conducted in accordance with ISO6865:2000 and ISO5983-2:2009 standard methods. The shell content in PURAFEX sample was determined in accordance with the *MPOB Test Method (2005)* as the key parameter to evaluate the pre-cleaning system performance without high kernel loss.

The crude fibre content in PURAFEX sample was lower than 12%, signifying better quality than commercial PKC (> 15%). The protein content in PURAFEX sample ranged from 16.0%-17.8%, while commercial PKC has <16.5% protein. The shell content in PURAFEX ranged from 4.0%-5.0%, while commercial PKC has shell content of >11.0%. The target performance of below 6.0% was thus achieved.

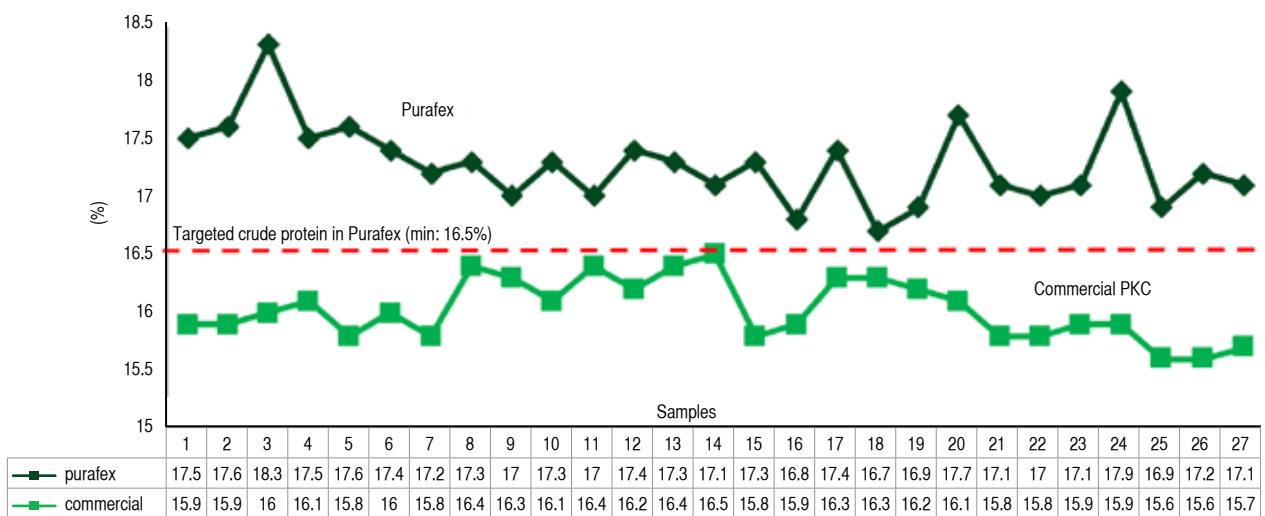


Figure 17. Comparison of crude protein content in PURAFEX and commercial PKC.

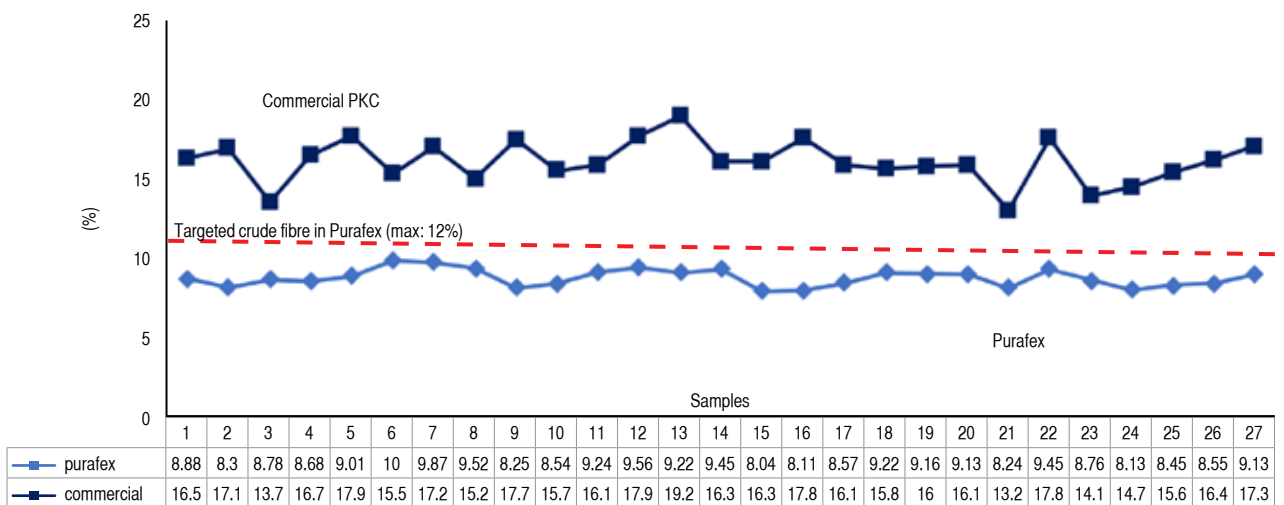


Figure 17. Comparison of crude protein content in PURAFEX and commercial PKC.

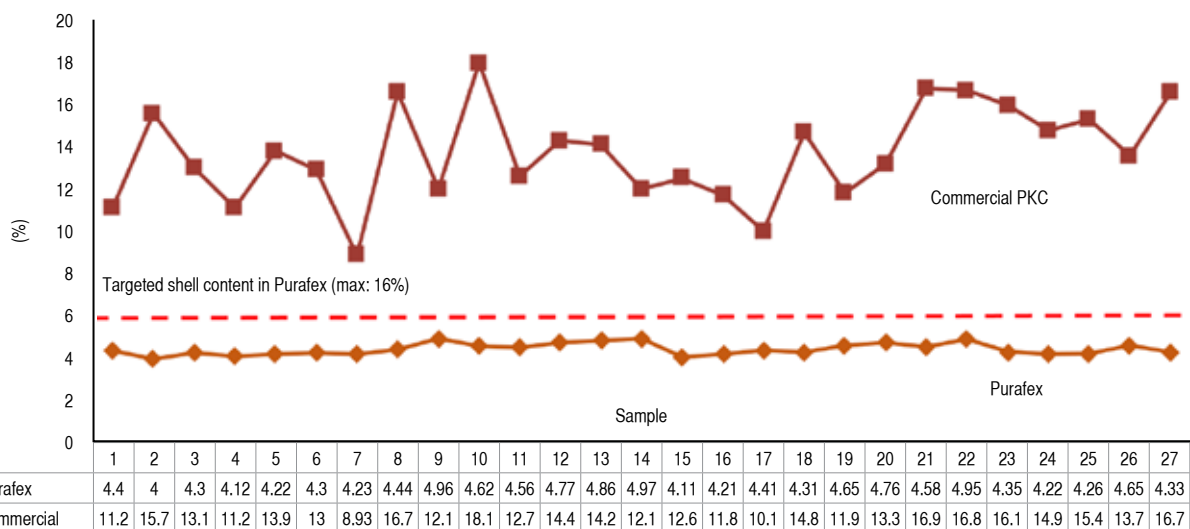


Figure 19. Comparison of crude fibre content in PURAFEX and commercial PKC.

AMINO ACID CONTENT IN PALM KERNEL CAKE

Generally, PKC either PURAFEX or commercial PKC is suitable for animal feed ingredient as it is rich in amino acid (Table 2). All essential amino acids are indicated in blue.

TABLE 2. AMINO ACID CONTENT IN PALM KERNEL CAKE

Amino Acid	Content (%)	Amino Acid	Content (%)
Alanine	0.66	Lysine	0.20
Arginine	0.54	Methionine	0.11
Aspartic Acid	0.91	Phenylalanine	0.60
Cystine	ND	Proline	ND
Glutamic Acid	2.73	Serine	0.57
Glycine	0.60	Threonine	0.36
Histidine	0.19	Tyrosine	0.21
Isoleucine	0.44	Valine	0.61
Leucine	0.80		

AWARD AND PRODUCT LAUNCHING

Chicken feed formulations with the inclusion of PURAFEX have won several recognitions, namely the International Invention, Innovation and Technology Exhibition (I-Tex 2016), Malaysian commercialization year (MCY 2017) and Exposition on Islamic Innovation (i-INOVA 2018) as shown in Figure 20.

PURAFEX and the pre-cleaning system were patented under patent no. PI 2017703180 and PI 2017703192, respectively, and launched on 25 April 2017 at Sime Darby Kernel Crushing Plant, Carey Island, Banting, Selangor (Figure 21).

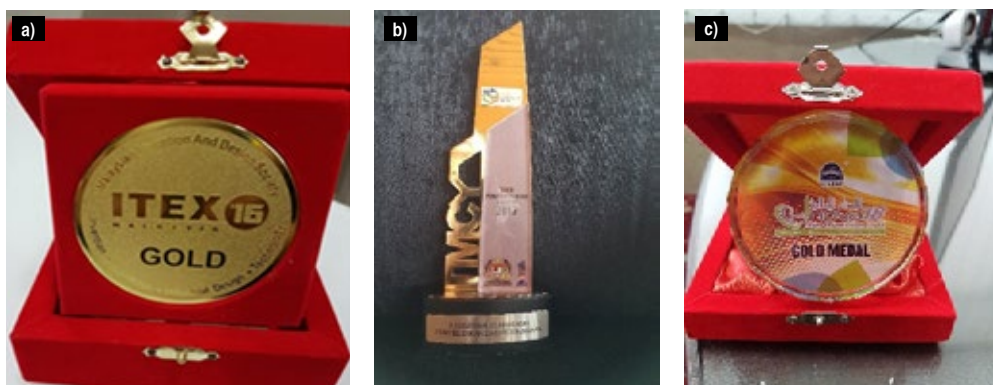


Figure 20. Awards received: (a) I-Tex 2016, (b) MCY 2017 and (c) I-INOVA 2018.



Figure 21. Premium PKC (PURAFEX) and pre-cleaning system launching ceremony at Sime Darby Kernel Crushing Plant, Carey Island, Selangor in 2017, officiated by YB Minister.

CONCLUSION

The quality of palm kernels should be prioritised as they are the sole raw material for PKC production. Due to some limitations, palm oil millers could not improve the kernel quality delivered to the crushing plant. Therefore, the use of a pre-cleaning system before kernel oil extraction is desirable to enhance the quality of the end products. The results obtained proved that the pre-cleaning system succeeded in reducing the shell content in the kernels, thereby enhancing the quality of premium PKC (PURAFEX).

ACKNOWLEDGMENT

Our deepest appreciation goes to the Director-General and management of MPOB for the permission to publish this article.

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