Palm Kernel Cake for Poultry

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Palm kernel cake (PKC), a by-product of oil extracted from palm nuts through expeller press or solvent extraction procedures is one of the highest quantities of locally available and potentially inexpensive agricultural products. PKC provides approximately 14–18% of crude protein (CP), 12–20% crude fiber (CF), 3–9% ether extract (EE), and different amounts of various minerals that feasible to be used as a partial substitute of soybean meal (SBM) and corn in poultry nutrition. Poultry's digestibility is reported to be compromised due to the indigestion of the high fiber content, making PKC potentially low for poultry feeding. Nevertheless, solid-state fermentation (SSF) can be applied to improve the nutritional quality of PKC by improving the CP and reducing CF content. PKC also contains β-mannan polysaccharide, which works as a prebiotic.

broiler growth performance nutritional value poultry palm kernel cake solid-state fermentation

1. Introduction

The livestock and poultry industries are vital to global industries that recorded consistent growth over the last 30 years. The poultry industry has relative advantages of being simpler in management, higher productivity, and faster return on investment than other livestock production [1]. The worldwide consumption of poultry products such as meat plus eggs is currently high and tends to grow continuously compared to other livestock products [2]. Poultry meat is an essential source of animal protein in human diets. Besides being moderately cheap and readily available, its composition makes it a necessary part of healthy and balanced diets [3]. The poultry sector is an integral part of Malaysia's livestock industry. Hence, Malaysia has been one of the world's highest poultry meat-consuming countries, with an annual consumption of poultry meat reaching up to 50 kg/person [2].

Costs of feeds have always been a significant concern in local poultry production [4]. Poultry production costs have continually increased because of the fluctuating prices of high-quality raw materials such as soybean, corn, and others [5]. Several initiatives have been put in place, such as finding cheaper and locally available materials as partial substitutable protein and energy sources instead of SBM and corn in poultry feed formulations. Various locally available and low-priced feedstuffs have been proposed but have not been satisfactorily acceptable for poultry and consequently used in small proportions [6]. Fluctuations in price and comparatively inadequate SBM supply, particularly during the Covid-19 pandemic, lead to city lockdown, and logistics limitation [7][8]. As a result, the discovery of alternative protein sources for poultry feeding diet has become a particular focus in the current scenario to decrease reliance on SBM as the main ingredient of protein in poultry feeds [9].

Generally, most agricultural industries produce large amounts of residue every year. If waste is not effectively managed, it could contribute to the environment and harm both human and animal health. Waste products from the palm oil extraction industry constitute a huge problem, and any initiative towards economic utilization is a positive step towards solving environmental pollution [10]. Some countries around the world produce plenty of local alternative feedstuffs which are by-products of the agricultural industry. More often, these materials such as wheat bran, rice bran, cottonseed meal, copra meal, PKC, palm kernel meal (PKM) wheat pollard, cocoa pods, oil palm fronds (OPF), palm oil mill effluent (POME), sugarcane bagasse, and cassava waste are widely used as livestock feeds [11][12]. Most of these by-products contain significant amounts of anti-nutritional factors (ANF) which are also considered as non-starch polysaccharides (NSPs) [11]. Locally, large quantities of PKC have been produced from the oil palm industry, and comprehensive studies are needed to assess its potential as alternative protein sources for poultry feeds [2].

Being the primary source of vegetable oil production, the oil palm tree (*Elaeis guineensis*) is one of the most critical trees in many tropical countries such as Brazil, Indonesia, Malaysia, Thailand, Columbia, and Ecuador [13]. PKC is a by-product after oil extraction, which is generally a good source of fat, protein, minerals, and carbohydrates [14]. Many studies have been conducted to assess PKC's feeding value and determine its effects on feeding diets in the broiler chicken industry. Malaysia is one of the world's largest palm oil producers with a large amount of readily available PKC. There is a need to use PKC in the poultry industry as a source of protein and energy [15]. The main objective of the palm industry is to generate palm oil. PKC derives from the nuts of palm fruits is generated as by-products [16].

PKC usage is common in ruminant diets but limited in non-ruminant, especially in poultry diets due to its high fiber content [6]. PKC can be a promising feedstuff for poultry feed because of its moderate CP (16.43%) content and energy [17]. Cellulolytic bacteria can significantly improve the nutrient quality of PKC through SSF [18][19].

2. Composition and Nutritional Value of Palm Kernel Cake (PKC)

PKC has been accepted as one of the components in animal feeds. Its nutritional values, attractive prices compared to other meals, and long-term availability make PKC more competitive in the international meal market [20].

There are two methods of palm oil extraction: expeller or screw press, and solvent extraction. PKC is the result of the expeller oil extraction procedure, while the solvent extraction technique yields PKM. Extraction with solvent generally produces less residual oil than the expeller process, whereas crude protein and crude fiber are higher in solvent-extracted PKM [21][22]. Therefore, the nutritional values of PKC and PKM differ depending on their method of extraction [10].

More than 75% of PKC are made from cell-wall components, which made up of 35.2% mannose, 2.6% xylose, 1.1% arabinose, 1.9% galactose, 15.1% lignin, and 5.0% ash [23]. β–mannan is the main component of palm kernel by-products NSPs which is regarded as a prebiotic and is known to enhance birds' immune system and reduce pathogenic bacteria in the small intestines [10].

The nutritional profile of PKC is shown in Table 1. It has a low nutritional value; however, processing and conversion through SSF could significantly increase its nutritional values and make it useful for poultry [10][22][23][24][25][26].

Table 1. Chemical composition of palm kernel cake (PKC) (%).

Nutrient	PKC [1a]	PKC [1b]	PKC [1c]	PKM [2a]	PKM [2b]	PKM [2c]	FPKM [3]	FPKC [4]	FPKC [5]	FPKC [6]	FPKC [7]
Dry matter	88.57	91.42	90.87	96.3	91.80	91.75	91.83	88.9	92.62	92.40	89.85
Crude protein	16.86	16.43	16.23	16.6	20.04	16.60	23.42	20.7	16.80	16.68	17.11
Crude fiber	15.12	-	-	14.6	15.47	12.29	12.44	11.3	-	-	14.59
Ether extract	6.82	-	4.12	8.3	8.63	7.59	3.89	4.07	-	-	5.15
Ash	6.58	4.47	5.10	4.3	7.56	3.88	8.33	18.9	4.67	4.80	5.40
Gross energy (Mcal/kg)	-	-	4153	4872	-	-	-		-	-	-
ME (Kcal/kg)	-	-	-	-	2792.1	2423	2655.9	2282.7	-	-	-
Nitrogen free extract (NPE)	54.62	-	-	-	-	51.39	-	45.0	-	-	57.75
Neutral detergent fiber (NDF)	-	82.29	61.54	-	-	-	-	39.8	71.70	73.54	-

Nutrient	PKC [1a]	PKC [1b]	PKC [1c]	PKM [2a]	PKM [2b]	PKM [2c]	FPKM [3]	FPKC [4]	FPKC [5]	FPKC [6]	FPKC [7]
Acid detergent fiber (ADF)	-	51.48	36.14	-	-	-	-	17.5	47.27	47.45	-
Hemicellulose	-	30.81	25.40	-	-	-	-	22.2	24.43	26.42	-
Cellulose	-	35.55	-	-	-	-	-	8.16	31/85	31.41	-

[1a] Untreated palm kernel cake [27]. [1b] Untreated palm kernel cake [28]. [1c] Untreated palm kernel cake [29]. [2a] Untreated palm kernel meal [30]. [2b] Untreated palm kernel meal [25]. [2c] Untreated palm kernel meal [31]. [3] Ensiled PKM; PKM was ground, sprinkled with water until wet (not dripping) then ensiled for 7 days [25]. [4] Degraded PKC; PKC was sprayed by extracts from *Aspergillus niger* and bags sealed for 7 days [32]. [5] Fermented PKC by *Paenibacillus polymyxa* ATTCC 842, for 9 days incubation period [28]. [6] Fermented PKC by *Paenibacillus curdlanolyticus* DSMZ 10248, for 9 days incubation period [28]. [7] Fermented PKC by *Trichoderma koningii* for 21 days [27].

3. Solid-State Fermentation (SSF) of PKC

SSF is a biotechnological process in which microorganisms grow in solid substrates in the absence of free water. The goal of SSF is to place cultured microorganisms in direct contact with the insoluble substrate to obtain the concentration of the maximum nutrients for fermentation from the substrate [33]. SSF appears to be a possible technology for the production of microbial products. It improves the nutritional value of agriculture by-products produced by agricultural industries as a residue [34].

As a result, SSF is used widely because of its economical and practical advantages over submerged fermentation such as using of wide variety raw materials with an extensive variation of substrate composition and size, low energy expenditure, less expensive, lesser fermentation space, easier control of contamination and high reproducibility [34][35].

4. Utilization of PKC as Livestock Feed

Palm fibers are safe as they are pure, non-carcinogenic, free of pesticides, and have soft parenchyma cells that can be processed and produced as animal feeds [36]. PKC is one of the highest quantities of locally available and potentially inexpensive feedstuffs in many tropical countries [27] (Table 2).

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Table 2. The recommended inclusion levels of PKC in livestock feed.

Livestock	Recommended Level (%)		References
	PKC	FPKC [1]	
Poultry—broiler	Up to 10	Up to 15	[17][37]
Poultry—layer	5–10	-	[38]
Swine	15–25	-	[39]
Freshwater fish	10–20	-	[39]

[1] Fermentation of PKC by *Paenibacillus polymyxa* ATCC 842 for 9 days incubation period.

5. Limitation to Using PKC in Non-Ruminant Nutrition

There is a limitation to using PKC in monogastric animal diets because of the high CF, coarse texture, and gritty appearance. Traditionally, PKC has not been used widely in pig and poultry diets. This mainly because of its unpalatability and high fiber content (150 g/kg DM). As a result, this reduces its digestibility for these animals [17]. The CF content of PKC, ranging between 16% and 18%, is considered high for non-ruminants. It may not be suitable if included at high levels in poultry or pig diets [6]. The presence of high content of NSPs in PKC prevents it from being widely used in poultry diets. Thus, SSF is employed to reduce NSPs [17][37]. Furthermore, PKC has different antinutritional factors like 0.40% tannic acid, 6.62 mg/g phytin phosphorus, 23.49 mg/g phytic acid, and 5.13 mg/g oxalate which has adverse effects on the nutritional quality of PKC [40].

6. PKC in Poultry Nutrition

Malaysia is one of the world's largest palm oil producers with abundant PKC available throughout the year. There is a need to efficiently utilize this by-product as an alternative feed for the local poultry industry [17]. The importation cost of corn and SBM dramatically influences the price of animal feedstuff in the country, making PKC an alternative feed ingredient. To poultry farmers, the primary factor in utilizing PKC is its relatively low price to be used as one of the ingredients in poultry diets [41]. The feed cost per/kg decreases with increasing levels of PKC [1][42][43][44]. Nonetheless, the challenge of using agro-byproducts as feed ingredients for poultry is the presence of fiber components in these materials. Since poultry has a simple digestive system, the inclusion of PKC in their feeding diet is limited because of the absence of fiber digestive enzyme activities in their gastrointestinal tract (GIT)

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[45]. Additionally, some essential nutrients such as amino acids and energy content in the PKC may influence the feed value.

Few researchers have reported variations of optimum inclusion level of PKC in poultry rations. The use of PKC in poultry depends on the type, age, and sex of the chickens, as well as the sources and variations of oil and shell content of the PKC [6][46]. Edwards et al. [41] suggested that PKC in poultry diets should be limited to 20%. The same finding by Arasse et al. [1] showed that broiler birds could utilize PKC-based diet up to 20% without adverse effects on their production performance. Furthermore, Ugwu et al. [47] also recommended that the 20% PKC can effectively replace maize for the finisher phase of broilers resulting in a better performance.

Furthermore, PKC inclusion in broiler chickens' diets improved the relative weights of immune organs and enhanced humoral immunity [48]. On the contrary, results obtained by Alshelmani et al. [17][37] showed that the inclusion of more than 10% untreated PKC in broiler diet might have adverse effects on birds' performance. These contradictory results may be attributed to the oil extraction methods from palm fruits, which leads to the differences in its composition. The findings obtained by Zanu et al. [38] showed that layers could utilize PKC-based diet better (up to 5 and 10% inclusion) without any adverse effects on their production. In contrast, the egg production was adversely affected consequent to 15% PKC supplementation.

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