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CORN AND COB MEAL: NUTRIENT COMPOSITION AND NUTRITIVE VALUE

*Taiwo K. Ojediran and Segun A. Olorunlowu**

Address(es): Segun A. Olorunlowu,
Department of Animal Nutrition and Biotechnology, Ladoke Akintola University of Technology, P. M. B. 4000, Ogbomoso, Nigeria.

*Corresponding author: olorunlowusegunabraham@gmail.com

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ABSTRACT

The need to broaden the varieties of feed ingredients available to livestock producers has prompted research into the use of non-conventional, low-cost, and typically abundant feed resources. While corn remains a primary source of energy in most feed rations, studies have proven that maize cobs are either dumped or burned for fuel; thus, they are available and widely abundant but not a usual feedstuff. Corn and cob meal (CCM) a product of grinding the grain and the cob together has potential as livestock feedstuff. The use of CCM is limited by accurate knowledge and application of its nutrient composition, especially fibre. With the right processing, the level of inclusion of CCM could be increased. Various researches have been carried out on CCM for livestock, but there is inconsistency amidst examined nutritive values for CCM, therefore diverse results exist from livestock studies. This paper reviews the nutrient composition of CCM and its value as an alternative energy and fibre source in livestock diets.

Keywords: Maize, Maize cob, ear maize, dietary fibre, ruminant, monogastric

INTRODUCTION

Maize (*Zea mays*), is undoubtedly part of the most explored food crops by man for its nutritional, medical and pharmaceutical, industrial and research benefits **(Adiaha, 2017)**. Maize remains the primary source of energy in both ruminant and non-ruminant diets **(Skoufogianni *et al.,* 2020)**, accounting for 30-50% of calories **(Shiferaw *et al.*, 2011)**. Maize is a widely used ingredient in animal feed production **(Dei, 2017)** due to its high nutritional value and availability **(Bathla *et al.*, 2020)**. It is a staple feed ingredient for various livestock and poultry species, including cattle, pigs, and fish **(Erenstein *et al.*, 2022)**.

Commercialized production of livestock requires the use of feed ingredients, not excluding maize **(Klopfenstein *et al.*, 2013)**, that are prohibitively expensive due to their comparative consumption by humans and animals. Climate change, competition for food and fuel, and decreased output have all resulted in large increases in maize prices **(Ojediran *et al.*, 2022)**. Maize prices grew by 71.16% between 2005 and 2015 (USDA, 2015). The COVID-19 pandemic expanded the price by 76-82% as a result of the disturbances created by covid-19 **(Ojediran *et al.*, 2021)**. As a result of this, feed prices have risen at an unprecedented rate, increasing the demand for cost-effective alternative feed ingredients.

Maize cob is a byproduct of maize processing that can be used together with maize grain, partially or wholly **(Kanengoni *et al.*, 2015: Blandino *et al.*, 2016; Babale *et al.*, 2018)**. It is a waste product **(Vasudeva and Rangaswamy, 2020)** of maize milling that has little or no end use **(Kanengoni *et al.*, 2015)**. Corn and cob meal (CCM) is a product of milling unshelled maize (whole corn grain and cobs) and can be fed fresh, ensiled, or dried. It is high in starch **(Meyer, 2015)** and can be used as an energy feed for animals, especially ruminants, with a nutritional value that is somewhat lower than maize grain but higher than maize silage **(Gillespie and Flanders, 2009)**. Because of the presence of cobs in it, CCM has more fibre **(Hill *et al.*, 1995: Kenyon, 2006: Meyer, 2015)** than grain, thus it can also serve as a fibre source alongside other nutrients **(Lardy and Anderson, 2010)**.

More than 60% of the output of maize production in developed nations is utilised in compounded feeds for poultry, pigs, and ruminant animals **(Goodla *et al.*, 2012)**. The rapid expansion of poultry production has raised the demand for maize. Poultry feed includes 60-65% maize **(Goodla *et al.*, 2012; Krishna *et al.*, 2014)**. Upon the utilization of this percentage in poultry feed, there is always a need to include fibre sources such as wheat offal, rice offal, maize offal, etc **(Jha and Mishra, 2021)**. The utilization of CCM in the replacement of maize and other fibre sources in poultry, pigs, and ruminant feed production would be a better option as it will not only be a means of meeting the nutrient requirement of animals but as a way of reducing the cost of production and utilization of the cob being a waste product.

This study delved into the nutritional composition and nutritive impact of CCM when fed. The nutrient composition of maize grain, cob, CCM, and their utilization in livestock production was evaluated from the data obtained from approximately 86 studies.

MAIZE GRAIN

Maize (*Zea mays L.*) is an essential staple food grain in many parts of the world, particularly in Africa, Latin America, and Asia, as well as a key feedstock in industrialised nations **(Awika, 2011)**. Maize is one of the most utilized crops by mankind for its nutrient content, medicinal value, pharmaceutical uses, herbal supplement, cost benefits, industrial benefits, and research purposes **(Adiaha, 2017)**. Wheat, rice, and maize are the three most researched food crops by mankind due to their enormous importance **(Erenstein *et al.*, 2022)**. Farmers across the world have identified and are cultivating several types of maize, including striped maize, popcorn, dent corn, flint corn, sweet corn, and amylo-maize **(Adiaha, 2017)**.

Maize has both food (grain, flour, syrup, oil, etc.) and non-food (cosmetics, adhesives, paints, varnishes) uses. Maize oil and starch are additional important products **(Ecocrop, 2010)** in which its grain is a key feed grain in poultry, pig, sheep, goat and cattle diets, where it serves as an energy source.

Maize production

Maize, along with wheat and rice, is the world's primary staple crop, spurred by increased demand and a mix of technical breakthroughs, productivity gains, and area expansion **(Erenstein *et al.*, 2022)**. Because of its widespread availability, maize has a broader range of applications, including direct human consumption, industrial food processing, livestock feed, and industrial non-food products such as starches, acids, and alcohol **(Goodla *et al.*, 2012)**. There has been an increase in the price of maize over the last decades (Figure 1). The price of maize rose by 31% during the previous two decades, from US$127/ton in 1994 to US$167/ton in 2020 **(Erenstein *et al.*, 2022; WorldBank, 2021)**. Following an earlier peak related to the global food crisis in 2008 (US$217), the highest annual maize prices for the period were reported in 2012 (US$271/ton).

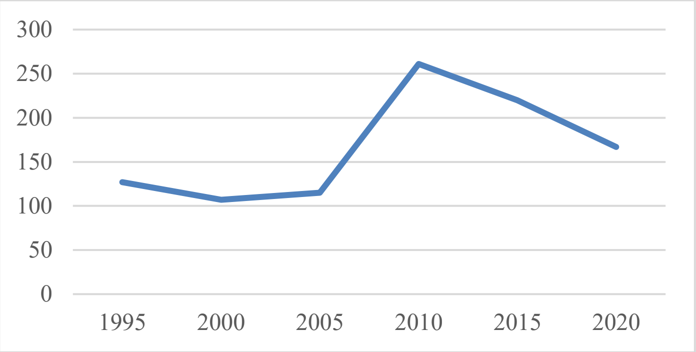

Figure 1 Maize prices (real US$/ton, 1995-2020). Source: WorldBank (2021)

Maize is the second world's leading commodity after sugar cane **(FAOSTAT, 2021)**. Figure 2 compares the values of the world's most produced commodities with sugar cane (28.03%), maize (15.09%), rice (11.62%), wheat (11.43%), raw milk of cattle (10.30%), potatoes (5.78%), oil palm fruit (4.58%), soya beans (4.45%), other vegetables (4.40%), and sugar beet (4.32%).

The majority of maize produced between 2000 and 2021 was produced in the Americas (51.60%) (Figure 3). The Americas thus contributed more than half of the global maize production followed by a third in Asia (29.90%) and the remainder primarily by Europe (11.10%) and Africa (7.40%). Northern America (mostly the United States) and Central and South America account for two-thirds of the maize produced by the Americas while Asia's maize area was from East Asia (primarily China, with generally temperate maize as opposed to mostly tropical maize in South and South-East Asia) **(Erenstein *et al.,* 2022)**.

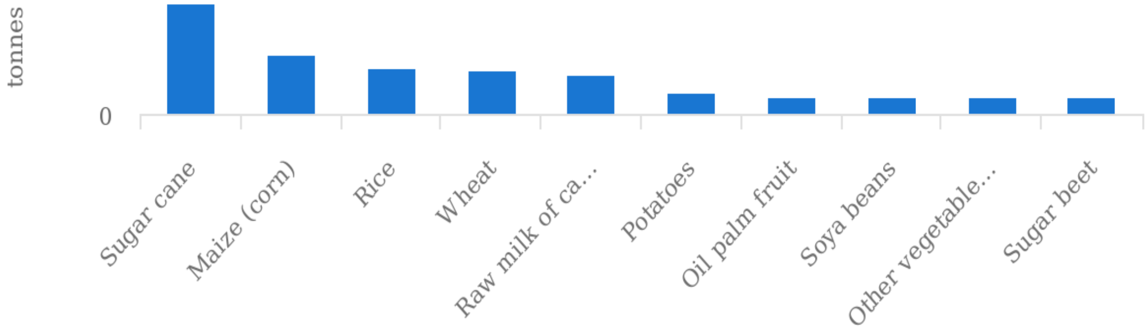

Figure 2 Most produced commodities, World + (Total) Source: FAOSTAT 2021

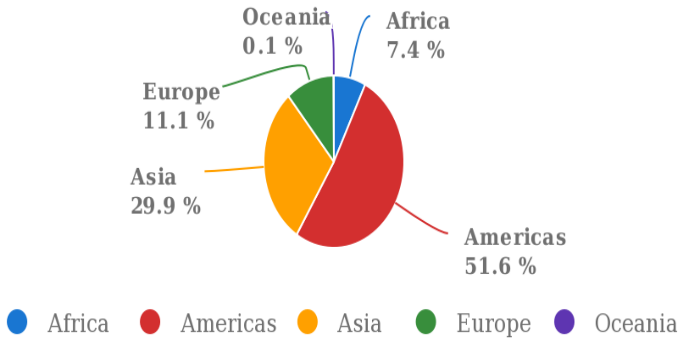

Figure 3 Production share of Maize (corn) by region Source: FAOSTAT 2021

There is a proportionality between the rate of the world's population and the demand for animal products, hence, the increase in the population has increased the demand for animal products, hereby, increasing livestock production **(Speedy, 2003)** and the demand for maize (an important feed resource in areas with high feed demand) **(Notenbaert *et al*., 2013)**. It can be concluded that the cost of maize (a feeding crop that is widely used worldwide in livestock production and nutrition) **(Yin *et al*., 2017)** is on the increasing side. This increase in the cost of maize as conventional raw material, increase in the rate of livestock production, expanding need for agricultural products, and competition for agricultural land between food, feed, and energy crops has accelerated the demand to find alternative feed resources that can replace or supplement a proportion of it in livestock nutrition at a lower cost of production **(Blandino *et al.,* 2016)**.

Nutritional composition and nutritional value of maize grain

Maize is composed of protein, crude fibre, ether extract, and carbohydrates. Maize supplies a significant quantity of energy in both human and livestock diets. The crop delivers amino acids to the body, albeit it lacks several critical amino acids like lysine and tryptophan **(Adiaha, 2017)**. Maize is composed of 80% carbohydrate, 10% protein, and 3.5% fibre, in addition to 2% mineral and vitamin **(IITA, 2001)**. Maize has a high starch content (about 65%), 4% oil, and 10% NDF **(Sauvant *et al.,* 2004)**. Maize starch ferments slower than other cereal starches, with 30% of it escaping rumen fermentation. Zein and glutelin are the primary protein in maize and they are situated in the endosperm and germ respectively **(McDonald *et al.,* 2002)**. Because zein, the most important, is lacking in lysine and tryptophan, amino acid supplementation is frequently required. Maize cultivars with improved amino acid profiles, such as Opaque-2 and Flour-2, have been developed **(McDonald *et al.,* 2002)**.

The proximate content of maize grain is shown in Table 1. **Enyisi *et al.* (2014)** reported the moisture content of maize grain to be within 11.60% and 20.00%, the ash composition to be within 1.10% and 2.95%, 4.50 – 9.87% crude protein, 2.17 – 4.43% ether extract, and 2.10 – 26.77% crude fibre. The values reported by **Kierończyk *et al.* (2021)** falls into the same category with the report of **Enyisi *et al.* (2014)**. The proximate composition reported by **Ape *et al.* (2016)** and **Onyango *et al.* (2004)** falls into the same range that was reported by **Enyisi *et al.* (2014)** except for the difference in the carbohydrate compositions. **Onyango *et al.* (2004)** reported 86.33±0.09% for carbohydrates while **Enyisi *et al.* (2014)** reported 44.80 – 69.60% for carbohydrates. **Samir *et al.* (1998)** reported the dry matter content of maize as 81.00% - 91.00%. There could be slight variation in the nutritional composition of maize which can be attributed to the maize variety used, environmental factors and agronomic practices **(Enyisi *et al*., 2014)**.

Table 1 Nutrient composition of maize grain

Parameters (%)	**A**	**B**	**C**	**D**	**E**	**F**
Dry matter	80.00-88.40	92.84	89.55-91.02	91.32±0.13	86.00 – 90.00	72.20
Ash	1.10-2.95	2.19	0.81-1.35	2.08±0.01	-	1.20
Crude protein	4.50-9.87	8.75	11.05-12.79	8.71±0.08	7.00	8.30
Ether extract	2.17-4.43	2.40	-	2.88±0.01	-	3.70
Carbohydrate	44.80-69.60	77.46	-	86.33±0.09	77.00	-
Crude fibre	2.10-26.77	2.40	0.79-2.48	-	1.20	2.20

A – **Enyisi *et al*. (2014)**; B – **Ape *et al*. (2016)**; C – **Shaista (2016)**; D – **Onyango *et al.* (2004); E – Dei. (2017); F - Kierończyk *et al*. (2021)**

Adequate knowledge of the proximate and mineral element compositions of maize and its availability will go a long way in providing substantive nutritional information and effective guidance on dietetics **(Enyisi *et al*., 2014)**.

Monogastrics and ruminants prefer maize grain as a source of energy **(Humer and Zebeli, 2017; Skoufogianni *et al.,* 2020)**. Because of its high carbohydrate and protein content **(Enyisi *et al*., 2014)**, at a 30% inclusion level, it encourages high milk production in dairy cows **(Saha *et al*., 2009)** and a sufficient supply of starch also encourages the development of rumen bacteria, which improves forage digestion, rumen cycling, and future feed intakes **(Saeed *et al*., 2018)**. Maize grain has a low acidogenic value **(Theurer *et al.*, 1999)** facilitating glucose absorption in the small intestine. To meet the needs of dairy cattle, however, maize grain must be suitably balanced with a protein source due to its low protein content.

Calcium deficiency in maize grain needs supplementation. Phosphorus is bound in phytate to the tune of 75%, making it unavailable to animals and reducing calcium availability **(Sauvant *et al*., 2004)**. To enhance P availability in monogastric, low-phytate hybrids have been produced **(Veum *et al*., 2001)**. Yellow maize has more vitamin A than white maize because of the presence of β-carotene, which is a source of Vitamin A known as Retinol **(Tawanda *et al.,* 2011)**. Vitamin A insufficiency has little impact on ruminants **(Shastak and Pelletier, 2023)** but it can be harmful to pigs and poultry if not sufficiently supplied with a vitamin A source.

MAIZE COB

Maize cob is a waste and byproduct of maize production that may be used as a supplement or replacement for maize grain in animal nutrition. This centre core of the maize can be obtained after the kernels have been removed **(Lin *et al*., 2020)**. In the United States, over 50 million tons of cobs were generated yearly in the 2000s, with the majority of them left on the field **(Jansen, 2012)**, and maize cobs constitute a substantial by-product in many maize-producing nations.

Maize cobs have lately been identified as a potential low-cost and promising feedstuff and source of renewable energy **(Jansen, 2012)** that can be used as an alternative source of energy **(Blandino *et al.,* 2016)**. Although maize cob utilization is rarely recorded, attempts have been made to explore potential applications worldwide; Nigeria **(Opeolu *et al.,* 2009; Raheem and Adesanya, 2011)**, Zimbabwe **(Chimonyo *et al.,* 2001; Mashatise *et al.,* 2005)**, Ghana **(Tuah and Orskov, 1989)**.

Because there is currently no farm-level maize cob harvesting technology or storage facilities **(Kanengoni *et al.,* 2015)**, it can be concluded that maize cob is a waste generated from maize processing that has little or no end use other than fuel in most parts of the world **(Njideka Evelyn Njideka *et al*., 2020)**. Therefore, in sub-Saharan Africa, Asia, and Eastern Europe **(Latif and Rajoka, 2001; Božović *et al.,* 2004; Zhang *et al.,* 2010)**, farmers burn the maize cobs for cooking and heating, plough them back into the ground, or simply discard them **(Kanengoni *et al*., 2015)**.

Nutritional composition and nutritional value of maize cob

Maize cob is categorized under lignocellulose biomass **(Kanengoni *et al*., 2015; Njideka *et al*., 2020)**. Its classification is due to its composition of cellulose (45% - 55%), hemicellulose (25% - 35%), and lignin (20% - 30%) **(Deutschmann and Dekker, 2012; Menon and Rao, 2012; Kanengoni *et al*., 2015; Njideka *et al*., 2020)**. It has been established that xylan accounts for around 50% of the hemicelluloses in maize cobs, and, like cellulose, it has strong water-holding capacities that induce digesta to bulk up when consumed **(Vazquez *et al*., 2006; Ndou *et al*., 2013; Njideka *et al.,* 2020)**. The Dry matter (DM), Crude protein (CP), Ether extract (EE), Ash, Crude fibre (CF), Nitrogen free extract (NFE), Neutral detergent fibre (NDF), Acid detergent lignin (ADL), Acid detergent fibre (ADF), Cellulose, and Hemicellulose of maize cobs are shown in Table 2. The average composition of maize cob as shown in the Table revealed that the fibre components (NDF – 77.40% DM, ADF – 52.30 % DM, and ash – 4.63 % DM) are higher than in wheat bran (NDF – 37.88 % DM, ADF – 11.13 % DM, and ash – 5.12 %DM) (Huang *et al.,* 2015). The average CP (2.54 % DM) and EE (0.97 % DM) of maize cobs (Table 2) are quite low compared to a conventional fibre source such as wheat bran (CP – 17.5 % DM and EE – 2.83 % DM) **(Huang *et al.,* 2015)**. Despite its low CP value, the widespread availability of maize cob, large quantities, easy and inexpensive procurement, and high cellulose and hemicellulose content increase its utilisation as an energy source in ruminant feed, particularly in areas or at times when better ingredients are unavailable **(Adebowale, 1992)**.

Table 2 Nutrient composition of maize cob

Nutrient (%DM)	A	B	C	D	AVERAGE
Dry matter	89.60	88.52	90.83	95.63±0.43	91.15
Crude protein	2.50	3.26	3.89	0.50±0.04	2.54
Ether extract	0.40	-	0.57	1.83±0.17	0.93
Ash	2.40	7.26	7.67	5.10±0.08	5.61
Crude fibre	34.70	-	28.69	-	31.70
NFE	49.60	-	-	-	49.60
NDF	68.70	92.98	70.63	-	77.44
ADL	-	-	16.88	7.05±0.02	11.97
ADF	48.00	57.32	51.58	-	52.30
Cellulose	-	-	34.70	26.96±0.18	30.83
Hemicellulose	20.70	17.96	19.05	40.71±0.21	24.61

A – **Donkoh *et al.* (2003)**; B – **Kanengoni *et al.* (2004)**; C– **Akinfemi (2010)**; D– **Njideka *et al*., (2020)**.

The stage of maturity, cultivar, climate, soils, and processing techniques have a significant impact on the nutrient composition of maize cob **(Szyszkowska *et al.,* 2007)**. The amount of NDF, ADF, and DM in matured cob is higher than the amount in less matured cob and at the same time more matured cob has lower CP than less matured cobs **(Kanengoni *et al.*, 2015)**. NDF refers to the cell wall composition of the cob which consists of the ADF fraction plus hemicellulose. Cellulose is a non-starch polysaccharide composed of alternating linear glucose units connected by β (1-4) glycosidic linkages and is the primary structural component of maize cell walls **(Kanengoni *et al*., 2015)**.

McDonald *et al.* (1998) reported that the advancing maturity of plants will result in an increase in the DM contents of plants and the cell wall contents (NDF, ADF, ADL and NFE) and a decrease in cell contents (CP, EE and ash). **Szyszkowska *et al. (*2007)** reported that there is a positive relationship between the DM of maize cob and the content of the starch and a negative relationship with the NDF and ADF fraction. NDF is important in ration formulation because it reflects the amount of feed the animal can consume. The negative relationship between the DM, ADF and NDF as reported by the aforementioned study aligned with the report of **Kanengoni *et al.* (2004)** and **Chimonyo *et al.* (2001)**.

Based on the processing method, **Boovi *et al.* (2004)** stated that 1-mm maize cobs have more CP and ether extract but lower cellulose, hemicellulose, ADF, and NDF than 3 and 2-mm particle-sized maize cobs.

Maize cobs have high potential and nutritive value that should be fully accessed **(Lin *et al*., 2020)**. It primarily contains cellulose (45% - 55%), hemicellulose (25% - 35%), lignin (20% - 30%) **(Deutschmann and Dekker, 2012; Menon and Rao, 2012; Kanengoni *et al*., 2015; Njideka *et al*., 2020)**, and a small amount of ash **(Lin *et al*., 2020)**. Maize cob is relatively high in crude fibre and poor in palatability **(Lin *et al*., 2020)**.

The digestibility of DM, NDF, ADF, hemicellulose, nitrogen, and energy will reduce when the inclusion level of maize cob in the diet increases resulting from an increase in the passage rate and sequestration of nutrients in the maize-cob-containing diet preventing its digestion **(Stanogias and Pearce, 1985)**. Maize cob can be regarded as a bulky feed due to its increase in fibre composition which can be used to slow down the rate of nutrient digestion **(Scazzina *et al.*, 2013)**. Soluble fibre attracts water in the gut, forming a gel, which can slow the rate of digestion. Through the inhibition of digestion and absorption of other energy-providing macronutrients in the diet, the energy value of the feed may be reduced **(Hervik and Svihus, 2019)**. **Baer *et al.* (1997)** and **Miles (1992)** also reported that there is a negative relationship between the fibre content of a feed and fat and protein digestibility in humans, thus, there is a negative relationship between the inclusion level of maize cob in diet and the fat and protein digestibility of the animal fed.

The anti-nutritional composition of maize cob (mg/100g) as reported by **Njideka *et al.* (2020)** is Oxalate (0.03±0.01), Phytate (0.80±0.02), Tannins (0.03±0.01), Saponins (2.23±0.07), Alkaloids (0.04±0.01), Trypsin inhibitor (0.24±0.03) and Hydrogen Cyanide (0.06±0.02). These values are all lower than those found in wheat bran, rice bran, barley bran, and oat bran **(Kaur *et al.*, 2011).**

In a study by **Ajayi and Ajao (2020)** where maize cob was utilized as the fibre source for broiler chicks, it was concluded that maize cob of up to 25% can be fed to broiler chicks without an adverse effect. However, it was also recommended that the diet of broiler chicks can constitute up to 25% of maize cob while a diet with 25 - 50% inclusion of maize cob should be meal supplemented with exogenous enzyme (Maxigrain®). This study mandated that there is a need for further study to determine the optimum level of maize cob inclusion in broiler chicken diets.

A study by **Zagi and Mahmud (2022)** affirmed that maize cob alongside another energy supplement can be used to reduce the cost of feeding ram. This study, however, furthered more by concluding that maize cob has no adverse effect on the growth of rams but no particular inclusion level was recommended. The primary barrier to the use of maize cob in pig diets is the lignocellulosic composition of maize cob, which is resistant to the digestive enzymes of pigs and consists of 45% to 55% cellulose, 25% to 35% hemicellulose, and 20% to 30% lignin **(Kanengoni *et al.*, 2015)**. In research by **Kanengoni *et al.* (2004)** on the effect of maize cob on the growth performance of pigs, the pigs' growth performance began to decline as the inclusion level rose to about 30%.

CORN AND COB MEAL (CCM)

Corn and cob meal (CCM), a valuable feed ingredient that is fed fresh, ensiled, or dehydrated consists of whole maize ears including the cobs and the grains. It is a homegrown feed resource that can be incorporated as a basal ingredient while formulating balanced and compounded feed **(Millet *et al.*, 2005)**. Depending on the harvesting technique, CCM consists of the maize grain and the cobs. CCM is occasionally a direct product of combine harvesters and includes solely grain and cobs **(Lardy and Anderson, 2010)** for finishing pigs as well as cattle, it is well-liked in European nations **(Meyer, 2015)**. It has a longer harvest window than the entire maize plant and may be harvested and processed at a later time **(Kenyon, 2006)**. Compared to high-moisture maize grain, it has more fibre, and unlike grain, it would not need extra roughage or related operating expenditures **(Hill *et al.*, 1995; Kenyon, 2006)**.

CCM can be harvested in a variety of ways and has a wide harvesting window with 60% to 70% DM **(Kenyon, 2006)**. According to **Lardy and Anderson (2010)**, a forage harvester fitted with a kernel processor is used to gather the ear, cob, and husk. Another method is to use an all-crop header on a forage harvester to cut off the top third of the stalk and all of the ears, however, because the stalks are left in the product, it has lower nutritional value. The cob can also be broken up and returned to the grain tank using a normal combine, producing a corn and cob mixture.

Due to the inability of monogastric animals to utilize fibre supplements compared to ruminants, the usage of this item as a feed supplement in monogastric nutrition is quite concerning. Although CCM is high in starch, it is typically viewed as being too fibrous for developing pigs **(Capraro *et al.*, 2014)**.

Nutrient composition and nutritional value of CCM

The stage of maturity of the plant, the cultivar, and the processing method are factors that affect the nutrient composition of CCM because they have an impact on the nutrient composition of maize, which will indirectly affect the nutrient composition of CCM **(Szyszkowska *et al.*, 2007)**. The percentage of grain to cob is another factor that determines the nutrient composition of CCM. The amount of cob in CCM ranges from 9% to 20% of the dry weight of unshelled maize, improving the feeding value compared to previously and occasionally coming very close to the maize grain itself. For instance, from 2011 to 2014, samples of CCM from Germany had about 3% crude fibre, which is only a little more than maize grain **(Meyer, 2015)**. However, CCM may contain much more fibre (up to more than 20% DM crude fibre) (husks, a portion of the stalk, etc.) due to different genetics, a different time of harvest, or the presence of additional fibrous components.

Late harvesting of maize causes the cob to become less digestible, lowering the calorie content of the diet when compared to dried grain. Before feeding, a nutritional study is suggested due to these causes of variation.

The method of processing (method of drying and the relative moisture content of the unshelled maize) **(Suri *et al.*, 2016)**, the screen size of the hammer mill **(Saensukjaroenphon *et al.*, 2017)** used during the processing, and the age of harvest of the maize **(Salama, 2019)** significantly influence the nutritional composition of CCM. A hammer mill with a lower screen size may produce CCM with a lower CF value as a result of the reduced amount of corn cob that will pass through the screen and be processed into CCM while a hammer mill with an increased screen size may produce CCM with a higher CF value.

There is a positive relationship between the crude fibre composition of CCM and the cellulose composition of the maize **(Dyer and Taylor, 2008)**, that is, the crude fibre increases with an increase in the cellulose composition which also increases with the plant’s maturity.

CCM contains more fibre than grain since it contains cobs and, occasionally, husks and pieces of stalk. Newer cultivars have substantially less cob, sometimes less than 10%, resulting in a product with superior feeding value than before, and in some cases very close to maize grain itself **(Meyer, 2015)**.

CCM is a starch-rich energy feed for livestock, especially ruminants, with a nutritional value that is higher than that of maize silage but somewhat lower than that of maize grain **(Kenyon, 2006)**. All classes of ruminants, including dairy cows, developing and finishing cattle, and sheep, can consume CCM, an energy-rich feed, including pigs, rabbits, and all classes of ruminants **(Kenyon, 2006)**. By preventing an excessive amount of fat accumulation, CCM may be beneficial for outdoor pig fattening **(Millet *et al.*, 2005)**.

Table 3 shows the nutrient composition of CCM as reported by **Millet *et al.* (2005)**. The composition as shown in Table 3 suggests that CCM is a feed ingredient that can be used in both monogastric and ruminant diets to replace energy sources like maize and fibre sources such as wheat bran, maize offal, etc. due to its relatively tolerable amount of crude fibre and higher crude protein value when compared with maize cob. A study carried out by **Ojediran *et al.* (2023)** reported the proximate and fibre composition of CCM (Table 4). While the average proportion of maize grain was 89.25% and the cob was 10.75%. 6.00% of insoluble Acid Detergent Fibre (ADF) and 10.01% of Hemicellulose were reported in this study.

Table 3 Analysed and computed nutrient composition of CCM

Parameters	Computed composition (%)	Analyzed composition (%)
Dry matter	-	63.43
Crude ash	1.27	1.16
Crude fibre	2.84	2.85
Crude protein	5.83	5.32
Ether Extract	2.70	3.72

Adapted from Millet *et al.* (2005)

Table 4 Proximate analysis of CCM

Parameters	Composition (%)
Dry matter	88.64
Crude protein	6.85
Crude fibre	26.80
Ether extract	2.40
Ash	1.95
Nitrogen free extract	62.00
Neutral detergent fibre	16.01
Acid detergent fibre	6.00
Acid detergent lignin	5.00
Hemicellulose	10.01
Metabolizable energy (Kcal/kg)	2648.85

Adapted from Ojediran *et al.* (2023)

CCM in ruminant diets

All kinds of ruminants, including dairy cows, growing and finishing cattle, and sheep, may consume CCM as an energy-rich diet **(Elly and Chappell, 1989; Kenyon, 2006)**. It may frequently be fed ground and ensiled and is typically a beneficial grain substitute for both practical and nutritional (cost, ease of harvesting, energy content) reasons. The considerable amount of roughage in CCM makes it a very safe diet with a low chance of acidosis. However, the nutritional value of CCM as a substitute for maize grain varies, and it could not give finishing steers enough energy. It is then required to feed CCM alongside protein and energy sources to this class of animal **(Lardy and Anderson, 2010)**. Ruminants thrive easily on CCM due to its palatability **(Gillespie and Flanders, 2009)**.

When compared to dry maize grain, high-moisture CCM (and high-moisture maize grain) appears to enhance total-tract and rumen starch digestibility while reducing milk fat, according to a meta-analysis of the literature **(Ferraretto *et al.*, 2013)**. For dairy cows, high-moisture CCM and maize silage were shown to pair effectively, with the diet combining these two items offering a decent balance of soluble carbohydrates **(Gillespie and Flanders, 2009)**. When compared to a comparable amount of high moisture maize grain, high-moisture CCM included at 20% (diet DM) in the diet of high-yielding dairy cows in Poland did not significantly affect DM intake, energy-corrected milk efficiency, fat content in milk, milk fatty acid profile, or protein efficiency, but the cost was lower **(Pysera *et al.*, 2012)**. The performance of dairy cows fed a diet containing 38% (diet DM) of high-moisture CCM in the USA was comparable to that of cows fed the same amount of cracked-shelled maize **(Broderick *et al.*, 2002)**.

CCM in pig diets

CCM is a locally produced feed component that may be used to fatten pigs **(Millet *et al.*, 2005)** but it is considered too fibrous for growing pigs. Due to its coarse form, automated feed delivery systems may have clogging issues **(Capraro *et al.*, 2014)**. To meet requirements for the inclusion of fibre in pig diets, it may, nevertheless, be a suitable element in diets for finishing pigs and pregnant sows **(EFSA, 2007)**.

CCM is a frequently used ingredient in the feeding of fattening pigs in Germany. It is advised to use German CCM at inclusion rates between 40 and 80% (on a fresh basis at 60% DM), in part because it has a similar composition to maize grain and has very little crude fibre (approximately 3% DM), it is, therefore, advisable to pay attention to the low amount of crude fibre and, if necessary, to take tryptophan supplements **(Meyer, 2015)**. To reduce the dietary intake of polyunsaturated fatty acids, which may impair the quality of the meat, it may be required to restrict the use of CCM silage in pig feeding **(Sommer, 2000)**.

When the fattening stage is prolonged until the pigs reach a slaughter weight of 160-170 kg, the inclusion of CCM silage (including the husks) in diets of heavy finisher pigs at moderate or medium rates (15-30% DM) was proved to generate a positive nutritional impact. This was believed to be a result of its prolonged gastric retention time and coarse particle size, which may have helped animals feel fuller for longer periods and prevented gastric acids from coming into direct touch with the stomach mucosa **(Mason *et al.*, 2013)**.

Pigs fed a diet containing 40% CCM silage had slower development because of the CCM's bulk effect, but this had the advantage of preventing excessive fat buildup **(Millet *et al.*, 2005)**.

CCM in poultry diets

The use of CCM in poultry diets is typically constrained by its high fibre content **(Göhl, 1982)**. According to the findings of several trials carried out in Germany in the late 1980s, CCM containing up to 7% crude fibre (DM) was highly palatable and could be used successfully as the only energy source, or in combination with cereal grains, for broilers and laying hens **(Roth-Maier and Kirchgessner, 1986; Roth-Maier and Kirchgessner, 1988)**. **Devegowda *et al.* (2008)** found that replacing maize with CCM in the diet of laying hens with a multi-enzyme had no adverse effects.

Potential constraints of CCM

CCM is susceptible to molding and can be contaminated with mycotoxins such as deoxynivalenol, zearalenone, ochratoxin A, and roquefortine **(Weidenbörner, 2012)**. It is recommended to test for mycotoxin levels in CCM before feeding livestock **(Meyer, 2005)**.

CONCLUSION AND RECOMMENDATION

The search for low-cost alternative energy and fibre sources for animal feed has been gaining ground in recent years. Corn and cob meal (CCM) is among one of the most promising and readily available alternatives that can be used as energy and fibre sources for animal feed. However, its application in animal production has been limited, largely owing to the lack of accurate proximate analysis of the ingredient and the fibre utilization rate of different livestock animals. Therefore, in the future, a detailed study on the appropriate inclusion rate for poultry, pigs, rabbits, ruminants, and other livestock is needed. To make the best use of CCM for economically effective animal production, an understanding of the nutrient composition and nutritive value of CCM and their availability to all kinds of animals is a must.

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