Copra meal and coconut by-products

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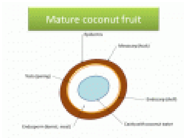


Common names

- Copra meal, copra cake, coconut meal, coconut cake, expeller copra meal, expeller copra cake [English]; tourteau de copra [French]; pasta de copra, torta de copra [Spanish]; コプラフレーク [Japanese]; 코프라 케이크 [Korean]; жмых копры [Russian]
- Dessicated coconut waste, paring meal

Species

Cocos nucifera L. [Arecaceae]

Feed categories

- Oil plants and by-products
- Plant products and by-products

Related feed(s)

Description

Copra meal, or coconut meal, is an important feed ingredient and the by-product of the oil extraction from dried coconut kernels (copra).

The coconut tree

The coconut palm (*Cocos nucifera* L.) is one of the most useful tropical trees. This multipurpose tree is used for food, beverage, shelter, animal feed, and is grown industrially for the edible and highly saturated oil contained in the flesh of its fruits. The tree can survive 50 years without needing much attention and the fruits drop throughout the year. The nut (see coconut structure scheme) has a smooth epidermis over a fibrous mesocarp (husk) that covers the hard endocarp (shell). A thin brown layer (testa) separates the shell from the endosperm (kernel, flesh, meat), which is approximately 1-2 cm thick. A cavity within the kernel contains the coconut water (Canapi et al., 2005).

Oil extraction

The coconuts are dehusked, split in half, drained of coconut water; then the halves are exposed to the sun for about a week, until the copra contains 6-8% water. Sun-drying is the cheapest method but if the weather is wet there is a risk of mold growth and aflatoxin contamination. Solar dryers reduce drying time and give products less likely to be contaminated. Coconut husks and shells can be used as fuel for artificial drying on bamboo grill platforms. In this case, direct exposure to smoke may give a light brown colour to copra and oil. Dryers equipped with a steel plate base give cleaner products (Canapi et al., 2005; Kurian et al., 2007). The dried copra is ground, flaked and cooked until moisture is brought down to 3%. The oil is mechanically extracted from the flakes using an expeller machine, resulting in a nearly colourless oil and a copra cake containing about 7% oil. This cake can be pelletized and used as a feed; it can also be solvent extracted, using hexane, resulting in meal containing less than 3.5% oil (Canapi et al., 2005).

On average, 1000 nuts yield 180 kg of copra, which contain 110 kg of oil and 55 kg of meal (Göhl, 1982). There is also a wet process that uses fresh kernels and provides high grade oil as well as valuable nutriments that are usually lost in the drying process (Canapi et al., 2005).

Coconut processing by-products

The main coconut by-product is the **copra meal**. Depending on the oil extraction method, the oil residue in the marketed product ranges from 1% to 22% (Göhl, 1982). The terms “copra cake” and “copra meal” sometimes refer respectively to the mechanically extracted and the solvent extracted product (FAO/IAEA, 2001). However, the names are often interchangeable in practice and in this datasheet copra meal will be used as a generic term to designate the oil by-product.

In addition to copra meal, other coconut products can be used to feed animals:

- **Copra** itself is usually too expensive to use as an animal feed, though it has been fed to pigs and poultry with good results. As copra oil contains only small amounts of unsaturated fatty acids, its consumption leads to firm body fat and good flavour (Göhl, 1982).
- **Fresh coconut flesh** and **parings** obtained after processing coconuts for direct human consumption are sometimes extracted to produce high-quality cooking oil or cosmetics (Aregheore, 2005; Göhl, 1982). The resulting oil meal is considered of higher value than copra meal: it contains a protein of higher biological value than that of coconut meal because it is not heat processed and it has more vitamins (Göhl, 1982; Grimwood et al., 1976).
- Young **coconut leaves** are relished by livestock but removing the leaves damages the tree, and animals should not enter coconut fields before the coconut trees are above grazing (Fuller, 2004).

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- **Coconut pith** resulting from fibre extraction is a rich source of soluble carbohydrates and is a potential source of energy for livestock (Viswanathan, 1980).
- **Coconut water** is usually wasted when the nuts are split open. The dry matter content of coconut water declines as the nut matures and is a meagre source of nutrients when the nuts are harvested for copra (Göhl, 1982).
- Other by-products of little or no feed value include the sediments recovered from the filter pads of the oil-straining presses, the coconut husks and the dust from processing the husks into fibre (coir dust), which has been suggested as a carrier for molasses (Göhl, 1982).

Distribution

Coconut palms mainly grow in coastal areas of the tropics and subtropics. They require a hot moist climate with average annual temperatures between 20 and 28°C, average annual rainfall ranging from 1000 to 1500 mm and deep alluvial or loamy soils (Orwa et al., 2009).

Copra meal is available worldwide. In 2010, world copra production was 5.2 million tons and world copra meal production was 1.86 million tons. The main producer of copra and coconut oil is the Philippines (42% of the oil production in 2009), followed by Indonesia (25%) and India (12%). Half of the production of copra meal is sold for export and the Philippines alone exports 0.5 million tons (62.5% of its production) (FAO, 2011; Oil World, 2011; USDA, 2013). Copra meal used to be a common feed ingredient in Europe, but importations have largely decreased since the 1990s, from 950,000 t in 1992 to 15,000 in 2013 (USDA, 2013).

Environmental impact

Coconut water

Copra production yields large amounts of coconut water whose nutritive value is very low when the coconut ripens. However, coconut water released in the environment may become a source of pollution and there have been attempts to use it as a substrate for growing food yeast and bacteria. It is also used as semen extender for artificial insemination (Taffin, 1993; Göhl, 1982).

Methane reduction

Coconut oil is particularly efficient in defaunating the rumen and reducing methane production. Adding copra meal to the diet gives comparable decreases in CH_4 to refined coconut oil, but also decreases growth performance which would result in an extended finishing time. This has implications for CH_4 emissions and production economics because of a longer animal lifetime (Jordan et al., 2006).

Datasheet citation

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Copra meal and coconut by-products

Nutritional attributes

Copra meal is a common feed ingredient, particularly for ruminants. Its crude protein content is 20-25% DM with relatively high quantities of cell wall constituents (NDF more than 50% DM, ADF about 30% DM). Its nutritive value is inferior to that of the other major oil meals, notably soybean meal, groundnut meal and cottonseed meal. Unlike those by-products, copra meal is often obtained from mechanical extraction only and its oil content is generally quite high (about 10% DM, in the 5-15% range, with values higher than 20% possible). The oil content makes it a valuable energy source, particularly in areas where such sources are scarce (Daghir, 2008). The less common solvent-extracted copra meal contains less oil (about 3% DM) and a little more protein (Feedipedia, 2011). Coconut oil differs from other common vegetable oils, in that it contains over 60% of medium-chain fatty acids (C8-C12), notably 46-50% of lauric acid (Gervajio, 2005).

A particularity of copra meal is its high non-starch polysaccharides content, and notably its levels of mannan and galactomannan (25-30%), which are known to have antinutritional properties in monogastric species. These constituents are also the cause of the low bulk density (0.56 g/cm^3 *vs.* 0.75 for soybean meal) and high water holding capacity (4.14 g water/g feed *vs.* 2.77 for soybean meal) of copra meal, physical properties that tend to limit intake (Sundu et al., 2009). However, copra meal can absorb up to half its own weight of molasses, which can be a useful property in compound feed manufacturing (McDonald et al., 2002).

Copra meal is poor in essential amino acids, notably lysine and sulphur amino acids (Sundu et al., 2009). Lysine may be partly destroyed by the heating during oil extraction (Pascoal et al., 2006). Amino acid supplementation may therefore be required.

Potential constraints

Rancidity

The high oil content of copra meal renders it susceptible to rancidity and the product should not be used after prolonged storage. Rancidity makes copra meal unpalatable and animals can start rejecting it even when there are no obvious signs of the rancidity (Ehrlich et al., 1990). Rancidity may also cause diarrhoea (Göhl, 1982).

The wet by-product from the oil extraction of fresh coconut flesh is highly perishable. It quickly becomes rancid and develops a foul smell. It must be used as soon as possible after processing, or dried in the sun or by other cheap means. Insufficient drying results in an unpleasant flavour and odour that affect intake and may cause total rejection of the diet (Aregheore, 2005).

Aflatoxins

During the sun-drying process, split coconuts are susceptible to mold and subsequent aflatoxin contamination. It mostly occurs when drying time is too short (2-3 days *vs* 5-7 days) or when the weather is wet (FAO/IAEA, 2001). In order to prevent mold growth, it is recommended to withdraw the coconuts that have been damaged during dehusking, and to avoid contact between split coconuts and the soil, as the latter is a source of contamination. Copra meal should not contain more than 12% moisture and should be kept in a well-ventilated store (FAO/IAEA, 2001).

Ruminants

Copra meal

Copra meal is a valuable feed for ruminants and can be used as a protein supplement for grass-fed animals, either alone or in combination with other protein sources. While theoretically inferior to other common oil meals due to its lower protein content, it is often a better feed resource than other local products such as cocoa by-products or brewer's grains (Aregheore et al., 2003). It is as effective as cottonseed meal for growth performance despite having half of the protein content, suggesting that the protein quality of copra meal has a higher biological value than that of cottonseed meal (Gulbransen et al., 1990).

Digestibility and energy values

In vivo OM digestibility of copra meal has been measured several times, particularly in studies comparing *in vitro* and *in sacco* the nutritive value of copra meal with other ingredients (Orskov et al., 1992; Chandrasekharaiah et al., 2001; Nguyen Nhut Xuan Dung et al., 2002; Woods et al., 2003a; Woods et al., 2003b; Carvalho et al., 2005; Chapoutot et al., 2010). Due to the low level of lignification of its cell walls, the NDF digestibility in copra meal is high, comparable to that of maize by-products and soybean hulls. As a consequence, *in vivo* OM digestibility of copra meal is good (75-85%) considering its relatively high NDF content (Woods et al., 1999; Sauvant et al., 2004; Aregheore et al., 2005). Higher values have been proposed for solvent-extracted meal than for expeller meal (85% *vs.* 79%, Schiemann, 1981). For the expeller meal, an OMD value of 76% (12.1 MJ/kg DM) has recently been proposed (Sauvant et al., 2004).

Protein value

The fraction of rapidly fermentable N in the rumen of coconut meal is low, with values ranging from 19% (Sauvant et al., 2004), 20.1% (Kiran et al., 2007), to 22.4% (Mondal et al., 2008). Therefore, if transit is taken into account, the effective degradability of copra protein is fairly low, about 50% (Woods et al., 2003a; Woods et al., 2003b, Sauvant et al., 2004, Mondal et al., 2008). The intestinal digestibility of copra meal by-pass protein, about 90%, is rather high compared to other feed ingredients (Woods et al., 2003c; Sauvant et al., 2004; Carvalho et al., 2005; Pereira et al., 2010).

Palatability

There are conflicting reports about palatability of copra meal. It was found to be very palatable and readily accepted by cattle (Gulbransen et al., 1990) but other authors observed that it decreased voluntary intake (Oliveira et al., 2010; Camacho Diaz et al., 2006). In one experiment with dairy cows, copra meal was not palatable initially and required about two weeks training to achieve satisfactory intakes, which then started to decrease (Ehrlich et al., 1990). The susceptibility of copra meal to rancidity after prolonged storage could cause such palatability issues, even when no obvious signs of rancidity are noticed (Oliveira et al., 2010; Ehrlich et al., 1990).

Dairy cows

Copra meal is a useful ingredient of dairy rations, supplying both energy and by-pass protein. A daily feed allowance of 1.5-2 kg has been recommended as the maximum safe amount (Göhl, 1982), but cows have been fed more than 3 kg/d without adverse effects (Ehrlich et al., 1990). Copra meal has been shown to be a suitable supplement for cows grazing tropical pastures in Fiji, where adding 1.8 kg/day of copra meal to the diet increased milk production by 70% (McIntyre, 1973). Cows grazing Napier grass (*Pennisetum purpureum*) and copra meal, providing 300 g/d of protein, increased production by at least 1 kg/day (Muinga et al., 1993). Less impressive results have been obtained on richer pastures, but copra meal could still replace sorghum grain and increase the fat content of the milk (Ehrlich et al., 1990). Earlier research suggests that copra meal makes butterfat harder, lending it a pleasant flavour, but large quantities of copra meal may result in tallowy butter (Göhl, 1982).

Beef cattle

Copra meal is a good supplement for grazing steers. Steers fed up to 1 kg/day of pelleted copra meal had a much higher growth rate than unsupplemented animals (0.41 *vs.* 0.11 kg/d) (Gulbransen et al., 1990). In growing steers grazing on giant stargrass (Cynodon plectostachyus), supplementation with copra meal gave higher growth rates than soybean meal (Ramos et al., 1998). Steers grazing Imperata cylindrica supplemented with copra meal, alone, or treated with molasses and urea, also had higher growth rates (Galgal et al., 2000). Average daily gains of 0.99 kg/day and diet intake of 3.2 kg/day were recorded on grazing buffaloes fed a supplement containing 70% copra meal. While these performances were satisfactory, they were lower than those obtained with a maize/soybean meal supplement and a 70% palm kernel meal supplement, possibly due to the lower palatability of copra meal (Oliveira et al., 2010). Copra meal at a daily rate of 500 g/head, and with rumen soluble nitrogen from urea, was found to be an effective supplement for improving growth of steers fed hay made from low quality forage (Hennessy et al., 1989).

Using copra meal in growing heifers resulted in decreased performance compared to a barley-soybean meal diet supplemented with copra oil. It was as efficient in reducing CH_4 production as the control diet, but the environmental benefit was cancelled by a longer finishing time (Jordan et al., 2006).

Sheep

Copra meal can be a suitable supplement for sheep and other ruminants consuming tropical pastures (Hammond et al., 1993; Galgal et al., 1994). Copra meal inclusion at 7.5% of the diet does not have negative effects on digestibility but decreases voluntary intake due to its poor palatability or other unknown effects (Camacho Diaz et al., 2006). Pelleted copra meal given to pregnant ewes increased birth weight of twin lambs, milk yield and ewe live weight after lambing (Bird et al., 1990).

Goats

Copra meal is often used as a protein supplement for grass-fed goats. Supplements containing up to 75% copra meal have been used successfully in goats fed Napier grass (*Pennisetum purpureum*) (Aregheore, 2006). Furthermore, supplementary diets consisting of 50% copra meal and 50% leucaena hay increased daily gain and diet digestibility (Mousoon et al., 1997). Copra meal could also be replaced by 75% of dried brewer’s grains (Aregheore et al., 2006).

Copra meal could replace up to 50% of soybean meal for goats fed corn silage, but 75% replacement reduced performance (Paengkoum, 2011).

Coconut waste from the extraction of fresh coconut flesh

The by-product of oil extraction from fresh coconut flesh is a good feed for ruminants and can be used fresh or dried. It provides an acceptable and very useful protein and energy supplement (Aregheore, 2005). Voluntary feed intake, live-weight gain and digestibility coefficients were mesured for goats receiving diets based on increasing levels of desiccated coconut waste meal. An optimal level of 38.5% replacement was found. This result is noteworthy because this material is available as a local feed source in the Pacific Islands (Aregheore et al., 2000).

Forage

Coconut orchards can be grazed when the leaves can no longer be reached by the grazing animals. It is often necessary to apply extra fertilizer to orchards that are being grazed as the coconut leaves tend to become yellow (Göhl, 1982).

Coconut water

Coconut water is sometimes fed to cattle in place of ordinary drinking water. At first it has purgative effect, but cattle soon become accustomed to it (Göhl, 1982).

Pigs

Copra meal may be an economical and valuable local feed for pigs that can be used to partially replace costly imported feeds such as soybean meal (Siebra et al., 2008; Kim et al., 2001; Thorne, 1992). However, the high fibre content of copra meal restricts its use in pig feeding. The slow rate of passage of fibre through the digestive tract results in decreased feed intake, lower availability of organic matter, protein and energy in the diet and poorer growth performance (Nguyen Nhut Xuan Dung et al., 2002; Noblet et al., 1993; Thorne et al., 1992; Lekule et al., 1986). The low concentration of essential amino acids, combined with the depressing effect on amino acid digestibility, makes amino acid supplementation necessary (particularly lysine, methionine+cystine and threonine) if high levels of copra meal are to be fed (Han et al., 2003; Mee et al., 1973; Thorne et al., 1992).

Maximum recommended inclusion levels are about 20-25% of the diet, but optimum should be nearer 10% (Pascoal et al., 2010; Siebra et al., 2009; Siebra et al., 2008; Nguyen Nhut Xuan Dung et al., 2002; O'Doherty et al., 2000; Lekule et al., 1986; Lekule et al., 1982). This level of inclusion yielded a gain of 500 g/d in growing pigs in Tanzania (Lekule et al., 1982). Inclusion rates higher than 50% depress the feed conversion ratio, but if growth performance at such rates is considered acceptable, the low cost of copra meal may decrease the cost per kg live weight (Mael et al., 2001; Göhl, 1982).

Feeding pigs on copra meal has no deleterious effect on meat quality parameters such as fatty acids or dressing percentages (Mael et al., 2001; Kim et al., 2001). It also produces firm fat in pigs (Göhl, 1982).

There is little literature on improving the nutritive value of copra meal for pigs. The addition of an enzymatic complex failed to improve it (Pascoal et al., 2010). Expander processing of the copra meal did not affect growth performance when the product was included at 15% of the diet (O'Doherty et al., 2001).

Poultry

Copra meal can be a valuable raw material in poultry diets, because of its availability at relatively low cost in some contexts.The amino-acid profile is not optimal for poultry due to a relative lack of lysine and sulphur amino-acids. The energy value of copra meal is low because of the high fibre content though it can be increased by the high content of residual oil in expeller meals. Energy values can be estimated by combining the values of defatted copra meal and copra oil. There appears to be a difference between the ME value of copra meal for young chicks, and for older birds and hens (Baidya et al., 1995).

The low feeding value in poultry is also partly due to physical properties of copra meal. The high water holding capacity and bulk tend to decrease intake, particularly in young animals (Sundu et al., 2005; Sundu et al., 2009). There is a significant effect of copra meal on the DM content of excreta (Panigrahi, 1989; Sundu et al., 2006). This can be a problem for both sanitation and quality of poultry litter.

Broilers

Several authors observed a decrease in performance at inclusion levels higher than 10-20% (Jacome et al., 2002; Sundu et al., 2004; Sundu et al., 2005; Sundu et al., 2006). Feed intake is lowered by low density and high water holding capacity of copra meal, and water consumption is increased (Panigrahi et al., 1987; Sundu et al., 2005).

Growth depression is particularly important in young animals, in which performance can be decreased with inclusion rates as low as 5% (Bastos et al., 2007). High inclusion rates can result in a 30 to 50% drop in weight gain (Sundu et al., 2006). The effect is less marked in older animals, because they gradually adapt and increase their feed intake and growth performance (Panigrahi et al., 1987; Jacome et al., 2002; Sundu et al., 2005; Bastos et al., 2007).

The physical presentation of copra meal has an important effect because it modifies bulk density. Crumbles, or coarsely ground pellets, appear to sustain a better growth rate than fine meal (Sundu et al., 2005; Sundu et al., 2006).

The use of enzymes (e.g. mannanases) to lower the effect of the fibre fraction has been tested. In most studies, there is a significant improvement in animal performance with enzyme supplementation, compared to untreated copra meal. However, the control diet without copra meal supported the best growth rate (Sundu et al., 2004; Sundu et al., 2005; Sundu et al., 2008). No particular effect on the quality of carcass was noted (Jacome et al., 2002; Bastos et al., 2007).

A general recommendation for using copra meal in broiler diets is to formulate feeds carefully, taking into account an evaluation of energy level (oil content) and the likely amino-acid digestibilities. The risk of a lysine deficiency should also be assessed. Spoiled or moldy samples should be avoided because of the mycotoxin risks. For optimal performance, copra meal should be limited to 10% of the diet, with no more than 5% in the diets of young animals. Some authors are even more restrictive (3% and 2%, Daghir, 2008). Presentation as crumbles or pellets is often preferred and increases feed intake. However, the incorporation levels can be higher when lower growth rates are acceptable, or in some situations where the low price of copra meal decreases production costs.

Layers

Several authors reported no loss of performance with up to 20% of high fat copra meal in the diet (Panigrahi, 1989; Braga et al., 2005; Lima et al., 2007). However with defatted copra meal, a small loss of body weight and egg production was observed above 15-20% in the diet compared to the isocaloric and isonitrogenous control (Moorthy et al., 2006b; Moorthy et al., 2010). No adverse effects were observed on egg composition (Barreto et al., 2006).

It is concluded that with adequate formulation (energy, amino acids), copra meal can be used efficiently in layer diets. In layers, it can be recommended to limit incorporation to 15%. This limit could be extended to 20% for good quality expeller copra meal. In pullet diets, it can be up to 10 to 20%.

Rabbits

Copra meal and coconut fibre are used in rabbit diets (Ravindran et al., 1986a; Hosein et al., 2010). Both products provide high level of fibre that is valuable for rabbits. While the level and quality of protein in copra meal protein are lower than those of soybean meal, copra meal may be a valuable and economical protein source for rabbits in areas where soybean meal is expensive (Haponik et al., 2009). Copra meal is also a good source of energy for rabbits and its gross energy, crude protein and oil are quite digestible. Copra meal can have a positive effect on rabbit meat quality: at 25% inclusion in the diet, copra meal lowers the palmitic acid content of rabbit meat without significantly affecting other fatty acids and may thus have a hypocholesterolaemic effect in humans (Souza et al., 2009).

Horses and donkeys

Copra meal is reported to have specific benefits for horses due to its low starch content, high digestible fibre and energy from the oil (Kempton, 2006).

Fish

Copra meal is a possible feed ingredient for fish though not a very good one. As a protein source, it contains much less protein than fish meal or soybean meal, and it is deficient in lysine and sulphur amino acids. While it is a good source of arginine, there is an antagonistic effect of excess dietary arginine on lysine metabolism and animals fed high dietary levels of copra meal may, therefore, suffer from lysine deficiency (Tacon et al., 2009). Supplementary lysine and methionine should be provided to fish fed copra meal (Hertrampf et al., 2000). Copra meal may also contain antinutritional factors, including phytic acid, tannins, and non-starch polysaccharides (Tacon et al., 2009). The high crude fibre content of copra meal is disadvantageous for aquatic feeds (Hertrampf et al., 2000).

Copra meal is more valuable to herbivorous and omnivorous fish (at 5-15% inclusion rates) rather than to carnivorous fish (at 5-10% inclusion rates) (Hertrampf et al., 2000).

Tilapia

Recommended inclusion levels are not consistent between authors. In Nile tilapia (*Oreochromis niloticus*) fingerlings, copra meal included in diets at levels varying from 15% to 30% resulted in similar growth performance, nutrient utilization and feed conversion ratio as the control diet (Santos et al., 2009a; Santos et al., 2009b; Olude et al., 2008; Pezzato et al., 2000). Lower inclusion levels (10% copra meal in combination with 25% fish meal) had been suggested in order to be efficient and economical (Guerrero, 1980). High digestible energy (14.8 MJ/kg) and good P availability have been reported (Pezzato et al., 2000).

In male Java tilapias (*Sarotherodon mossambicus*), a diet containing 25% protein from copra meal supported growth comparable to the control diet, but a 50% level produced lower growth rates (Jackson et al., 1982).

Cyprinidae

In grass carp fry (*Ctenopharyngodon idella*), which are carnivorous until 25-30 mm long, copra meal had a deleterious effect on feed intake and growth performance when it replaced 33% of zooplankton in the diet, or when it replaced 25% protein feed in the diet (Hasan et al., 1997; Silva et al., 1981). The poor pelletability of copra meal may make it difficult to maintain particle size during feeding, thereby affecting negatively feed intake in carps (Hasan et al., 1997).

In rohu (*Labeo rohita*) fingerlings, copra meal supplemented with amino acids could replace up to 50% of dietary fish meal and thus represent more than 60% of the total diet (Mukhopadhyay, 2000). A former experiment had shown that soaking defatted copra meal, in order to remove tannins, had a positive effect on acceptable inclusion levels of this feed (Mukhopadhyay et al., 1999).

Datasheet citation

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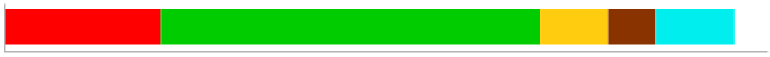
- Coconut, copra, fresh
- Coconut, coir dust
- Coconut, water

Avg: average or predicted value; SD: standard deviation; Min: minimum value; Max: maximum value; Nb: number of values (samples) used

Coconut, copra, oilmeal, expeller extraction



Main analysis	Unit	Avg	SD	Min	Max	Nb
Dry matter	% as fed	91.5	1.5	88.5	94.8	240
Crude protein	% DM	22.4	1.2	19.6	24.9	257
Crude fibre	% DM	14.2	2.1	10.1	19.7	251
NDF	% DM	54.7	4.8	43.9	61.7	35 *
ADF	% DM	28.7	3.4	22.3	36.5	28 *
Lignin	% DM	6.7	1.9	4.5	12.8	110 *
Ether extract	% DM	9.8	2.7	5.2	18.4	163
Ash	% DM	6.8	0.5	5.7	8.0	231
Total sugars	% DM	11.4	2.4	7.8	15.8	12
Gross energy	MJ/kg DM	20.1	1.5	18.8	23.8	18 *

Minerals	Unit	Avg	SD	Min	Max	Nb
Calcium	g/kg DM	1.2	0.4	0.6	2.2	56
Phosphorus	g/kg DM	5.8	0.5	4.5	6.8	60
Potassium	g/kg DM	20.1	1.8	17.3	23.9	27
Sodium	g/kg DM	0.6	0.4	0.1	1.0	8
Magnesium	g/kg DM	3.0	0.3	2.5	3.6	27
Manganese	mg/kg DM	84	37	43	128	9
Zinc	mg/kg DM	73	49	45	214	11
Copper	mg/kg DM	33	5	26	44	12
Iron	mg/kg DM	964	1019	63	2964	6

Amino acids	Unit	Avg	SD	Min	Max	Nb
Alanine	% protein	4.0	0.1	3.9	4.2	4
Arginine	% protein	10.7	0.9	9.4	11.3	4
Aspartic acid	% protein	7.7	0.3	7.4	8.1	4
Cystine	% protein	1.2	0.2	0.9	1.4	5
Glutamic acid	% protein	17.8	1.6	16.6	20.2	4
Glycine	% protein	4.1	0.1	4.0	4.3	4
Histidine	% protein	1.9	0.1	1.8	2.1	4
Isoleucine	% protein	3.0	0.1	2.9	3.2	4
Leucine	% protein	5.9	0.2	5.7	6.2	5
Lysine	% protein	2.6	0.2	2.3	2.9	8
Methionine	% protein	1.3	0.3	1.0	1.8	5
Phenylalanine	% protein	4.1	0.3	3.8	4.5	4
Proline	% protein	3.4		3.4	3.4	2
Serine	% protein	4.4	0.2	4.1	4.6	4
Threonine	% protein	3.0	0.1	2.8	3.2	5
Tryptophan	% protein	1.3				1
Tyrosine	% protein	2.1	0.2	1.9	2.2	3
Valine	% protein	4.7	0.3	4.3	5.1	4

Ruminant nutritive values	Unit	Avg	SD	Min	Max	Nb
OM digestibility, Ruminant	%	79.7		77.0	81.0	2 *

Energy digestibility, ruminants	%	79.1				*
DE ruminants	MJ/kg DM	15.9				*
ME ruminants	MJ/kg DM	12.8				*
Nitrogen digestibility, ruminants	%	76.5		76.5	91.0	2 *
Nitrogen degradability (effective, k=6%)	%	49	11	26	66	13

Pig nutritive values	Unit	Avg	SD	Min	Max	Nb
Energy digestibility, growing pig	%	55.5	9.6	55.5	85.4	5 *
DE growing pig	MJ/kg DM	11.2	0.9	11.2	15.2	7 *
MEn growing pig	MJ/kg DM	10.4	0.4	10.4	14.0	3 *
NE growing pig	MJ/kg DM	7.1				*
Nitrogen digestibility, growing pig	%	70.9	9.9	50.2	77.5	9 *

Poultry nutritive values	Unit	Avg	SD	Min	Max	Nb
AMEn broiler	MJ/kg DM	8.7		7.5	10.0	2

Rabbit nutritive values	Unit	Avg	SD	Min	Max	Nb
Energy digestibility, rabbit	%	66.1				*
DE rabbit	MJ/kg DM	13.3				1
Nitrogen digestibility, rabbit	%	57.7				1
MEn rabbit	MJ/kg DM	12.6				*

The asterisk * indicates that the average value was obtained by an equation.

References

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Coconut, copra, oilmeal, solvent extraction

Main analysis	Unit	Avg	SD	Min	Max	Nb
Dry matter	% as fed	89.8	1.4	86.3	91.7	18
Crude protein	% DM	23.5	1.3	21.3	25.6	23
Crude fibre	% DM	16.8	1.9	13.9	19.8	19
NDF	% DM	56.4	6.5	44.6	65.8	9 *
ADF	% DM	30.7	5.4	24.1	41.3	9 *
Lignin	% DM	8.0	2.4	4.7	13.2	18 *
Ether extract	% DM	2.8	1.6	0.4	5.4	16
Ash	% DM	7.0	0.3	6.6	7.6	20
Gross energy	MJ/kg DM	18.7	1.1	18.0	21.1	9 *

Minerals	Unit	Avg	SD	Min	Max	Nb
Calcium	g/kg DM	0.7	0.2	0.5	1.0	6
Phosphorus	g/kg DM	6.5	0.5	6.1	7.3	7
Potassium	g/kg DM	22.8	1.8	20.1	24.5	5
Sodium	g/kg DM	0.6				1
Magnesium	g/kg DM	3.3	0.2	2.9	3.5	5
Manganese	mg/kg DM	62	10	51	70	4
Zinc	mg/kg DM	68	15	56	89	4
Copper	mg/kg DM	36	9	25	43	3
Iron	mg/kg DM	1228	1704	200	3195	3

Amino acids	Unit	Avg	SD	Min	Max	Nb
Lysine	% protein	2.1				1

Ruminant nutritive values	Unit	Avg	SD	Min	Max	Nb
OM digestibility, Ruminant	%	78.7	3.3	69.9	78.7	3 *
Energy digestibility, ruminants	%	77.2		65.8	77.2	2 *
DE ruminants	MJ/kg DM	14.5		12.2	14.5	2 *
ME ruminants	MJ/kg DM	11.5				*

Nitrogen digestibility, ruminants	%	76.7		48.9	76.7	2 *
a (N)	%	18.6		14.7	22.5	2
b (N)	%	79.5		77.5	81.4	2
c (N)	h-1	0.040		0.030	0.049	2
Nitrogen degradability (effective, k=4%)	%	58				*
Nitrogen degradability (effective, k=6%)	%	50		42	70	2 *

Pig nutritive values	Unit	Avg	SD	Min	Max	Nb
Energy digestibility, growing pig	%	52.7				*
DE growing pig	MJ/kg DM	9.9				*
MEn growing pig	MJ/kg DM	9.2				*
NE growing pig	MJ/kg DM	6.3				*
Nitrogen digestibility, growing pig	%	67.9				*

The asterisk * indicates that the average value was obtained by an equation.

References

AFZ, 2011; CIRAD, 1991; Dewar, 1967; Friesecke, 1970; Grillet, 1992; Krishnamoorthy et al., 1995; Mondal et al., 2008; Nehring et al., 1963; Woods et al., 1999; Woods et al., 2003

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Coconut, copra, fresh

Main analysis	Unit	Avg	SD	Min	Max	Nb
Dry matter	% as fed	50.7		50.0	51.3	2
Crude protein	% DM	8.6		7.4	9.7	2
Crude fibre	% DM	3.7		3.0	4.3	2
Ether extract	% DM	66.2		64.4	68.0	2
Ash	% DM	2.5		2.0	2.9	2
Gross energy	MJ/kg DM	32.1				*

Minerals	Unit	Avg	SD	Min	Max	Nb
Calcium	g/kg DM	0.3				1
Phosphorus	g/kg DM	2.6				1

Pig nutritive values	Unit	Avg	SD	Min	Max	Nb
Energy digestibility, growing pig	%	84.4				*
DE growing pig	MJ/kg DM	27.0				*
Nitrogen digestibility, growing pig	%	83.8				1

The asterisk * indicates that the average value was obtained by an equation.

References

Lim Han Kuo, 1967; Loosli et al., 1954

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Coconut, coir dust

Main analysis	Unit	Avg	SD	Min	Max	Nb
Dry matter	% as fed	87.1				1
Crude protein	% DM	2.3				1
Crude fibre	% DM	34.2				1
Ether extract	% DM	0.7				1
Ash	% DM	7.6				1
Gross energy	MJ/kg DM	17.5				*

The asterisk * indicates that the average value was obtained by an equation.

References

Naik, 1967

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Coconut, water

Main analysis	Unit	Avg	SD	Min	Max	Nb
Dry matter	% as fed	5.2				1
Crude protein	% DM	4.4				1
Crude fibre	% DM	6.5				1
Ether extract	% DM	6.0				1
Ash	% DM	12.3				1
Gross energy	MJ/kg DM	16.9				*

Minerals	Unit	Avg	SD	Min	Max	Nb
Calcium	g/kg DM	57.7				1
Phosphorus	g/kg DM	38.5				1

Pig nutritive values	Unit	Avg	SD	Min	Max	Nb
Energy digestibility, growing pig	%	79.9				*
DE growing pig	MJ/kg DM	13.5				*

The asterisk * indicates that the average value was obtained by an equation.

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Oyenuga, 1968

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- Dan Iserman
- Valérie Heuzé / AFZ
- Amolnaik3k
- Hélène Thiollet, AFZ

Copra meal and coconut by-products

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- Dan Iserman
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