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Feeding value of copra meal for broilers

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The production of copra meal in some parts of the world is abundant and cheap and hence its inclusion in poultry diets would benefit the poultry industry. Its use as a feeding material would also be beneficial for the coconut industry and the environment, through the reduction of copra waste. However, the nutritional and physical qualities of this by-product are poor, and consequently, there has been limited use of this material in poultry diets. Attempts to improve the quality of this feedstuff have been made through supplementation with amino acids and enzymes as well as physical treatments such as pelleting, soaking and grinding. This paper reviews some issues of using copra meal as a poultry diet and aspects of dealing with the problems.

Keywords: copra meal; physical treatment; enzyme and broilers

Introduction

Attempts to replace conventional feedstuffs, *e.g.* corn and soybean, in poultry diets have been made for many decades because the supply of these feedstuffs is not secure in many parts of the world and their use for poultry feed is in competition with their uses for human foods and bioenergy. Using alternative feedstuffs is problematic for a number of reasons, chief among which are that many of them contain anti-nutritional factors and have low digestibilities.

One alternative feedstuff, which has several advantages over others, is copra meal (CM). CM is the by-product of oil extraction of the endosperm of coconut. This by-product is rich in protein (15-25%) and carbohydrate (60%). However, its inclusion in poultry diets is limited due to low levels of several essential amino acids, especially lysine and methionine (Thomas and Scott, 1962; Lachance and Molina, 1974). In addition, the carbohydrate is regarded as generally unusable fibre consisting principally of mannan, galactomannan and cellulose (Balasubramaniam, 1976; Dusterhoft *et al.*, 1992 and Knudsen, 1997), and the meal has a low bulk density (0.56 g/cc) (Sundu *et al.*, 2004b). Efforts have been made to increase its utilisation and feeding value through amino acid supplementation (Panigrahi, 1992), enzyme addition (Pluske *et al.*, 1997) and physical modification such as pelleting, crumbling

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and soaking (Sundu *et al.*, 2005a). This paper reviews the feeding value of CM and efforts to improve its feeding quality for broilers.

Feeding value of copra meal

CM is obtained from the coconut fruit which has been sun-dried or mechanically dried. CM is generally produced by the extraction of oil from the coconut kernel using expeller machines or solvent extraction (*Table 1*).

Table 1 Nutrient content and physical characteristics of copra meal.

Fractions	Composition	References
Dry matter (%)	90-96	(1) (3)
Crude protein (%)	15-25	(1) (2) (3)
Gross Energy (K Cal)	4,247 - 5872	(1) (3)
NDF*	60-62	(1)
Crude fiber (%)	7-15	(1) (2) (3) (4)
Lipid (%)	7	(1)
Ash (%)	6-8	(1) (4)

*NDF: Neutral detergent fibre; (1) Sundu *et al.,* 2004b; (2) Thorne *et al.,* 1989; (3) NRC, 1994; (4) Panigrahi *et al.*, 1987.

The quality of CM available commercially varies from one batch to another. There are three main factors, apart from its intrinsic nutrient content and its physical properties that influence CM quality as a poultry feedstuff. These include the extraction process, storage conditions and the drying process. Studies on the effects of different extraction processes on the quality of CM have been undertaken by a number of workers (Thorne *et al.*, 1989: Thomas and Scott, 1962). Solvent extracted CM is better quality in terms of protein content and quality (Thomas and Scott, 1962) than expeller CM. Heating is generated in an expeller machine and this can lead to thermal damage of the protein. Humid storage conditions impair the quality of CM due to the possibility of aflatoxin growth on the product. Sutikno (1990) found that 58% of CM tested was contaminated by aflatoxin, particularly aflatoxin B1 (Pue *et al.*, 1991). These two findings were reported from Indonesia and Papua New Guinea, which are high humidity countries. The amount of aflatoxin in CM exponentially increased when it was stored for more than five weeks (Head *et al.*, 1999). Drying is also found to be a factor affecting CM quality as a result of heat damage of protein (Guarte *et al.*, 1996).

Copra meal protein

Copra meal protein content varies depending on the coconut origin and the type of oil extraction process. Solvent-extracted coconut protein content tends to be higher, (24.6%; Thorne *et al.*, 1989) and 25.5%; Rama *et al.*, 1965) than the protein content of expeller pressed coconut meal, (15.4–21.8%; Thorne *et al.*, 1989). With a total world production of CM of 2 million tonnes/year (FAO, 2002), this is equivalent to more than 480,000 tonnes of crude protein which is available for animal feeding from CM.

Copra meal is generally low in lysine and sulphur amino acids (see *Table 2*). CM only meets 45–50% and 34–62% of the lysine and methionine requirements respectively for young chicks (NRC, 1994 and Lachance and Molina, 1974). The low content of lysine,

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coupled with the susceptibility of lysine and other amino acids to binding in the Maillard reaction during heating either in the drying or oil extraction process, indicates that amino acid quality can be low. Other amino acids such as tryptophan and threonine are not sufficient to meet chicken needs (NRC, 1994). Therefore the utilisation of CM as a source of protein can lead to a deficiency of amino acids, especially if it is used as a high proportion of a diet. Arginine content, on the other hand, is relatively high and thus increases the arginine to lysine ratio. Since arginine and lysine have an antagonistic effect (D'Mello and Lewis, 1970), an appropriate ratio should be ensured when the diet is fed to chickens. However, Balnave *et al.* (1999) stated that the high arginine to lysine ratio in CM can improve the resistance of animals to heat stress.

Table 2 Amino acid content of two copra meals (A and B) (gkg^{-1}).

Protein	(A)	(B)	0 – 3 weeks old broiler requirements (A)	The ability of 100 % copra meal A and B to meet amino acid requirements (%)	
				A	B
Crude protein	192.0	219.0	23	83.5	95.2
Arginine*	19.7	23.2	12.5	157.6	185.6
Cysteine	2.8	NC	(Cys + Meth) 9.0	62.2	34.4
Glycine	8.2	6.0	(Glycine + Serine) 12.5	128.8	102.4
Histidine*	3.6	2.4	3.5	102.9	68.6
Isoleucine*	6.3	5.0	8.0	78.8	62.5
Leucine*	11.8	9.9	12.0	98.3	82.5
Lysine*	5.0	5.5	11.0	45.5	50.0
Methionine*	2.8	3.1	(Cys + Meth) 9.0	62.2	34.4
Phenilanine*	8.8	6.0	(Phenyl + Tyrosine) 13.4	98.5	70.9
Threonine*	5.8	4.8	8.0	72.5	60.0
Tyrosine	4.4	3.5	(Phenyl + Tyrosine) 13.4	98.5	70.9
Serine	7.9	6.8	(Glycine + Serine) 12.5	128.8	102.4
Valine*	9.1	7.8	9.0	101.1	86.7
Tryptophan*	1.2	1.4	2.0	60.0	70.0

A: NRC (1994); B: Lachance and Molina (1974)
NC : Not calculated, *Essential amino acids

The solubility of coconut protein has been found to be low. An enzymatic study of coconut protein was done by Lachance and Molina (1974), who compared various enzymes used for extraction of protein. Their findings indicated that the inclusion of bromelain gave a higher solubility (0.35), followed by fungal prolase (0.28) and papain (0.26). In addition to these results, Krishnamoorty *et al.* (1995) stated that protein solubility of CM using protease enzyme was about 0.45. These findings indicated that different enzymes have different protein extractabilities. The digestibility of CM protein is variable depending upon the animal species used and the coconut extraction process. An *in-situ* study by Chandrasekariah *et al.* (2001) indicated that protein degradability of CM in the rumen was only 0.33. Studies in other monogastrics (pigs) showed that coconut protein digestibility was about 0.51 (Creswell and Brooks, 1971). No data is available on the digestibility of CM protein in broiler chickens. Unpublished data indicates that the faecal digestibility and ileal digestibility of CM protein for broiler chickens are 0.55 and 0.63 respectively.

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Copra non starch polysaccharides (NSPs)

Three of the earliest and still the most commonly used methods for identification of complex carbohydrates or fibre are the crude fibre method and two detergent methods. Over the last two decades, modified methods have been developed to analyse non-starch polysaccharides (see Knudsen, 2001). More than 60% of the nutrient components of copra have been analysed as neutral detergent fibre (NDF) which is mainly cellulose and hemicellulose (see *Table 1*). This indicates that the major component of coconut carbohydrate is in the form of dietary fibre. Coconut NSPs have been isolated, characterized and quantified by a number of workers. An early study by Balasubramaniam (1976) indicated that NSPs in coconut are mostly in the form of mannan (26%), galactomannan (61%) and cellulose (13%). Studies on the digestibility of coconut mannan in poultry diets are not available. Galactomannan, another major polysaccharide in coconut meal, is made up of a chain of β (1-4) –D-manopyranose units to which the galactose residue attaches as a side chain of D-galactopyranose units (Aspinal, 1970). Rao and Bagchi (1961) found mannan and galactomannan but not glucomannan in CM. A more recent study by Saittagaroon *et al.* (1983) demonstrated that mannan is the major polysaccharide in coconut meal and represents 61% of total polysaccharides., and the residue of alkali extraction found by the author contained mannose (42%) and glucose (58%). The presence of mannose and glucose found can be interpreted as glucomannan or a mixture of mannan and cellulose. From these two studies it may be hypothesized that copra NSPs are mainly cellulose and mannan as their presence was identified by a previous study of Balasubramaniam (1976) and neither Rao and Bagchi (1961) nor Balasubramaniam, (1976) found the presence of glucomannan in the coconut meal. Supporting the finding of Saittagaroon *et al.* (1983), Dusterhoft *et al.* (1991) stated that mannan is the predominant NSP in coconut meal.

A comprehensive study on the comparison of NSPs in several feedstuffs has been carried out by Knudsen (1997). The researcher found that copra meal contained 42.2% NSP, mostly as water insoluble non-cellulosic polysaccharides. Coconut monosaccharides are water soluble (such as galactomannan; Aspinal, 1970) and water insoluble (such as mannan; Aspinal, 1970). Non-cellulosic polysaccharides contain arabinose, xylose, mannose, galactose and glucose (Knudsen, 1997), although this research did not identify or quantify the kind of NSP. After examining the monosaccharide residues in CM, several NSPs can be expected to be present, including arabinogalactan and galactomannan. This prediction seems to be relevant to the findings of Saittagaroon *et al.* (1983), who identified small amounts of arabinoxygalactan, galactomannan, arabinomannogalactan and galactoglucomannan, all of which contain some of the monosaccharides identified by Knudsen (1997).

Physical properties of copra meal

Physical properties of the feed can be used as predictors to determine the feeding value of the ingredients and diets (Mratz *et al.*, 1957 and Kyriazakis and Emmans, 1995). Two important physical characteristics that should be considered in poultry diet formulation are bulk density and water holding capacity (WHC). These two physical characteristics may be associated with the chemistry of the constituent of polysaccharides and lignin (Eastwood, 1973) and play important roles in decreasing feed intake (see Kyriazakis and Emmans, 1995) which is subsequently impairs the productivity of birds.

The low bulk density (see *Table 3*) and high WHC of CM contribute to a decreased feed intake of birds due to its high bulking properties (see Sundu *et al.*, 2005b). The

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mechanism of these two physical characteristics affecting feed intake is that a low bulk density diet occupies more space in the digestive tract. This becomes critical when bulky ingredients have a high WHC. The ability of CM to bind water led to the birds consuming more water than the birds fed a lower WHC diet (Sundu *et al.*, 2005a). This led to less feed and nutrients being consumed. It is clear that the low feeding value of CM is not only contributed by its high dietary fibre and imbalanced nutrients, but also by its physical properties.

Table 3 Physical characteristics of copra meal compared with other feedstuffs.

Feedstuffs	Bulk density (g/cm^3)		Water holding capacity (g water/g feed)	
	Unmodified	0.5 mm	0.5 mm	1.0 mm
Copra meal	0.56	0.49	4.14	4.69
Palm kernel meal	0.67	0.57	2.93	3.52
Corn	0.69	0.56	1.71	1.94
Wheat	0.72	0.66	2.49	3.29
Rye	0.73	0.57	2.32	3.36
Triticale	0.69	0.65	3.08	3.47
Soybean meal	0.73	0.58	2.77	3.30
Millrun	0.36	0.44	4.16	6.64

Amino acid and enzyme supplementation

Despite the fact that CM is rich in protein (up to 25%), and can thus meet the crude protein demands for young chicks and adult broilers, its quality was reported to be low due to two major reasons: (1) heat treatment (during either the drying or oil extraction processes) depresses the nutritive value because of the sensitivity of protein to heat damage (Butterworth and Fox, 1963), (2) the high fibre content of the CM (cellulose and hemicellulose) interferes with the digestibility of nutrients (Rama *et al.*, 1965) as protein is located inside the cell which is surrounded by the fibrous cell wall. Accordingly, the inclusion of CM in the diet without any nutrient adjustment should be limited as it could impair the performance of the birds. To cope with these two problems, both the addition of essential amino acids, to supplement the low content and to replace the heat damaged amino acids, and enzyme application, particularly mannan degrading enzymes to break down the cell wall, are possible adjustments.

Early recommendations for using CM in broiler diet were limited to 20% inclusion rates. However, it was found that for young chicks (21 days), the inclusion of CM in the diet at only 10% gave a negative effect on the productivity of the birds kept for 2–3 weeks (Sundu *et al.*, 2004a, 2004b). Efforts to increase the inclusion of CM in the diet have been made by Thomas and Scott (1962) through supplementation with lysine. The authors formulated a 40% CM diet with three different energy contents. They found that the addition of lysine increased body weight of broilers. However when it was compared with a corn-soy diet, the growth of broilers was still low. More recent findings indicated that the use of up to 25% was still safe provided that two essential amino acids, lysine and methionine, were included and the birds were maintained to 6 weeks of age (Panigrahi *et al.*, 1987).

Sundu *et al.* (2005b) increased the inclusion of CM to 30% when supplemented with lysine and methionine in a diet balanced for metabolisable energy and digestible amino

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acids. When the birds were kept up to 6 weeks, the final body weight of birds was far below the body weight of birds fed the control corn-soy diet. This may justify the conclusion that a diet balanced for amino acids and metabolisable energy can only be tolerated at the level of 25% CM by broilers.

The inability to improve the feeding value of CM by amino acid supplementation in young chicks may be due to the smaller capacity of the digestive systems of young chicks (Sundu *et al.*, 2004b) and poor capability to release and digest nutrients inside the cell wall such as protein. These two problems led to a decreased weight of food consumed and therefore decreased nutrient intake. It is not difficult to conclude that when the birds consume small amounts of feed containing major components of indigestible nutrients, the bird's productivity is impaired.

Supplementation with exogenous enzymes could help to break down the dietary fibre. The efficacy of using enzymes has been proven in numerous publications, especially with respect to the use of glucanases in barley and xylanases in wheat (Ravindran *et al.*, 1998). Since β-mannan is the major component of copra carbohydrates, supplementation with mannan degrading enzymes could be beneficial. In the laboratory, the use of mannan degrading enzymes hydrolysed crude fibre (possibly containing mannan and cellulose), by up to 50% (Teves *et al.*, 1989). A detailed laboratory study by Kusakabe and Takashi (1988) indicated that copra mannan was hydrolysed into a small amount of mannose (3.3%), a large amount of mannobiose, mannotriose and mannotetraose (75.3%) and some manno-oligosaccharides (21.4%). Few studies have been documented regarding the use of enzymes to improve the quality of CM. One of the first studies on the use of enzymes in a CM-based diet was reported by Pluske *et al.* (1997), who found that the use of a mannan degrading enzyme improved body weight and decreased mortality of broiler chickens (*Table 4*). Manganese enzyme increased the dry matter digestibility and AME of the diet (Sundu *et al.*, 2004b). Protein, lipid and crude fibre digestibilities were improved when the CM was initially hydrolysed overnight with enzyme solution before CM was included in the diet (Teves *et al.*, 1989).

To maximise the feeding value of CM, the use of multi-enzyme mixtures may increase the digestibility of the nutrients. This is due to the fact that mannan and galactomannan only represented about 36% of total dry matter (Balasubramaniam, 1976; Knudsen, 1997) and the remaining dry matter consists of other NSPs, protein, lipid, starch and vitamins and minerals, which are essential for maintenance, growth and production. Sundu *et al.* (2005a) combined two enzyme products, a mannan degrading enzyme and a multi enzyme mixture (Allzyme SSF®), and found that body weight of birds were improved significantly so that they were not significantly different from those of birds fed a control corn-soy diet.

Table 4 Performance of chicken broilers fed a copra meal based diet treated in various ways.

Treatment	Control (-) Treated (+)	Age (days)	Body weight (g)	Feed intake (g)	FCR
Supplementation with amino acid (lysine)*	-	49	1268	-	2.29
	+	49	1269	-	2.18
Addition of enzyme **	-	42	1880	3344	1.78
	+	42	1931	3418	1.77
Soaking diet***	-	42	2331	3343	1.50
	+	42	2423	3379	1.50
Pelleting/crumbling copra meal***	-	42	2331	3343	1.50
	+	42	2674	3843	1.47

* Thomas and Scott (1962); ** Pluske *et al.* (1997); *** Sundu *et al.* (2005b)

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The pattern of growth of birds fed a 25% CM diet compared with a control (corn-soy) diet was reported by Panigrahi *et al.* (1987). Body weight and feed intake of birds fed the CM diet were significantly lower before the birds reached six weeks of age but after then they were not different. This reveals the considerable adaptive capacity of birds by increasing feed intake to the level of those fed a corn-soy diet. When Sundu *et al.* (2005a) increased the inclusion rate of CM to 30% in the diet, the body weight of birds was lower than controls at six weeks of age, even though there was a tendency for the birds to accelerate their growth during weeks five and six. However when the 30% CM diet was supplemented with a combination of enzymes, the authors found the same pattern as the earlier finding of Panigrahi *et al.* (1987) in which birds fed the supplemented diet could increase their growth rate after five weeks of age. This indicates that enzymes work well in older birds. This hypothesis is based on the fact that the passage time of digesta in older birds was longer than in young chicks (Duke, 1986). In the older bird, the enzyme has a longer reaction time in the digestive tract of bird, and this will, in turn, improve feed digestibility and the performance of birds.

Physical treatment of copra meal based diets

WATER TREATMENT

The main problem of using CM in the diets of young chicks may be related to its low bulk density and high WHC (Sundu *et al.*, 2004a) rather than because of its chemical properties. Bulk density of the diet has a positive correlation with fibre content in the ingredients in terms of crude fibre and NDF. Many polysaccharides in the diet with high WHC give viscous solutions when dissolved in water. However, the main polysaccharide in CM, β-mannan, does not cause viscosity but behaves like a sponge. These two physical properties may play an important role in decreasing feed intake of birds. The feed intake of birds fed a high bulk density diet appears to be higher (Panigrahi *et al.*, 1978; Sundu *et al.*, 2004b) while a diet with a high WHC has a negative correlation with feed intake (see Kyriazakis and Emmans, 1995; Sundu *et al.*, 2004a) but had a positive correlation with water consumption compared with a corn-soy diet (Sundu *et al.*, 2005a).

Soaking the diet has been reported to increase the performance of birds (Yalda and Forbes, 1996) through the mechanisms of activation of endogenous enzymes in the ingredients (Forbes, 2003), increase in ingredient solubilisation (Yasar and Forbes, 2000) and increase in bulk density (Sundu *et al.*, 2005a). Sundu *et al.* (2005a) found that soaking the 30% CM based diet, in a ratio 1:1 increased body weight significantly. Although these indicated promising and encouraging effects of soaking the CM based diet, it is still not certain which ingredients in the diet are affected most by water treatment since the whole diet was soaked. The improvement in body weight of birds fed a soaked CM-based diet was associated with a increase in feed intake, which may have been partly due to an increase in passage rate (Forbes, 2003) or to an increase in bulk density (Sundu *et al.*, 2005a). Although soaking food increased its solubilisation, and would allow rapid penetration of digestive enzymes (Yasar and Forbes, 2000) and softening of ingredients, the digestibility of nutrients in the CM based diet was not improved (Sundu *et al.*, 2005a). The increase in rate of passage of digesta may be the reason for the increase in feed intake.

Weekly live weight gain of birds fed the soaked diet revealed that in the first two weeks the growth of birds was impaired due to low feed intake (Sundu *et al.*, 2005a). After three weeks, feed intake was improved. Although soaking the diet may increase broiler performance, other disadvantages may discourage farmers from applying this type of diet on a commercial basis. The time taken to soak the diet, the difficulty of designing a

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trough suited for wet feed and wet litter are a few examples of the disadvantages of using wet foods (Forbes, 2003). Moreover, our study indicated that when a soaked CM based diet was kept at room temperature for two days, the diet became mouldy. Hence, extra effort is needed to replace the diet daily. In a small scale poultry farm, this system may be adopted using strict feeding management. This could be through a system of offering feed in a trough to the broilers at not more than 1.25 times their previous intake. Additional amounts of the diet can be offered when none of the diet is left in the feed trough. This can save time and limit diet refusal.

Pelleting and crumbling

Low bulk density ingredients like CM will occupy more space in the digestive tract of bird and this can affect the capacity of digestive organs to hold digesta. Accordingly, the birds fed the low bulk density diet consequently consumed less food as found in all studies on the use of a CM diet (Thomas and Scott, 1962; Panigrahi, 1992; Sundu *et al.*, 2004a). Sundu *et al.* (2005a) pelleted and crumbled CM and then added it to broiler diets, whereby the bulk density increased by 25%. This would benefit handling, transport cost and less space occupied for storage.

The use of pelleted diets has been practised for more than 65 years since the report of Patten *et al.* (1937) was published. The positive effect of using pelleted diets both in management and feeding value has been well documented (Callet, 1965; Thomas and Van der Poel, 1996; McCracken, 2002). There is no doubt that the body weight and feed intake of broilers fed a pelleted diet are improved (Mitchell *et al.*, 1972). Improvements in the body weight of birds fed a pelleted diet are thought to be realised through three main mechanisms;

(1) the increase in feed intake
(2) the increase in feed digestibility
(3) less energy spent.

Increased feed intake of pelleted diets compared with a mash has been reported by a number of workers. Pelleting the whole diet has been found to be beneficial for the improvement of bird performance (Callet, 1965; Proudfoot and Hulan, 1982; Nir *et al.*, 1995). Accordingly, pelleted diets are the main commercial product in the broiler industry today.

As the main problem of CM in the diet appears to be its low bulk density, pelleting CM alone, instead of the whole diet, may still give a positive effect on improving bird performance. To verify this hypothesis, Sundu *et al.* (2005a) initiated a study of adding pelleted CM to the diet. The authors found that pelleting CM increased the body weight of broilers to the extent that it overtook the body weight of the birds fed a corn-soy control diet due to increased feed intake but feed digestibility was not changed. This finding may justify the conclusion that the main contributing factor to an increased feeding value of pelleted or crumbled CM is its increased bulk density. Although CM may undergo chemical change during pelleting or crumbling, this effect seems not to benefit the birds as the feed digestibility remained unchanged (Sundu *et al.*, 2005a). Our unpublished data supports this hypothesis because when pelleted or crumbled CM was reground and fed to the birds, their growth was very slow.

This finding justifies the conclusion that pelleting is needed when the diet contains low bulk density ingredients. The growth response of broilers fed the pelleted/crumbled CM diet was optimal from day one. However, further studies are needed to verify this finding

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for other low bulk density ingredients. Just pelleting and crumbling the low bulk density ingredient also needs to be compared with pelleting and crumbling the whole diet.

Conclusions

Since some conventional feedstuffs are not secure and are expensive, especially in certain Asian and Pacific countries, CM, which is abundantly available in these regions, should be exploited fully for its potential use in feeding broilers. It is reasonably good to replace conventional feedstuffs with CM as this feedstuff can be successfully used in broiler diets up to the level of 30% from day one provided a balanced diet is formulated through the supplementation of amino acids, and the CM is processed by pelleting and crumbling to increase its bulk density. The satisfactory performance of broilers fed the crumbled CM based diets reveals that there is no problem of using CM in broiler diets from the aspects of palatability and anti-nutritional factors. It is a common problem for high crude fibre feedstuffs, such as CM, to have low digestibilities. As long as feed intake can be enhanced to increase the total digestible nutrient intake, the low digestibility may be compensated for.

Pelleting or crumbling CM increased feed intake and body weight. Hence, using a pelleted CM diet is recommended. However, pelleting and crumbling may not be available in CM producing countries, particularly in remote areas where CM is produced. An alternative method to pelleting is to soak the diet. Soaked diets are able to increase productivity but the practicality of using wet mash should be considered. However, the use of soaked diets may just suit the small scale poultry industry in which labour cost and time are not major considerations. The large scale poultry industry should practice pelleting CM diets as this type of diet gave a very large improvement in the productivity of broilers. In addition, the use of enzymes in CM diets improves bird performance to the non-significant level of body weight of birds fed corn-soy diet.

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