doi:10.1017/S0043933912000839

Potential use of beta-mannan from copra meal as a feed additive for broilers

B. SUNDU[1]*, U. HATTA[1] and A.S. CHAUDHRY[2]

[1]Animal Husbandry Department, Agriculture Faculty, University of Tadulako, Palu, Indonesia, 94118; [2]School of Agriculture, Food and Rural Development, Newcastle University, Newcastle Upon Tyne, NE1 7RU United Kingdom
***Corresponding author: b_sundu@yahoo.com**

The uses of a prebiotic to replace antibiotic growth promoters, mycotoxin and cholesterol binders in broiler diets have been commonly practiced over the last three decades. Many products have appeared commercially to replace antibiotic growth promoters and to tackle the problems of mycotoxins contamination. Mannose-based carbohydrates, particularly mannan-oligosaccharides from yeast, appear to have properties of coping with the mycotoxin related problems. Over the last three years, studies on the use of copra-mannan (CM) in this respect have produced promising results. CM has been found to effectively improve bird performance. When the birds were challenged against *Escherichia coli*, the supplementation of the feed with CMs was able to maintain growth performance of birds to the same level as the growth of birds fed commercial mannan-oligosaccharides or antibiotics. Contamination of feed with 0.3 ppm aflatoxin B1 reduced feed digestibility, but not when the feed was mixed with CM. The supplementation of the diet with CMs protects the birds from wet droppings when the birds were challenged by either *Escherichia coli* or aflatoxin contamination. Since there is a conflicting information about using mannans in the diet, particularly between using legume mannans as an antinutrient and yeast mannans as a pronutrient, this paper reviews the potential use of CMs for the purposes of promoting growth and improving health status of broiler chickens.

Keywords: CM; pro nutrient; mycotoxin binder; broilers

Introduction

Since coconut oil is the main commercial product in many coconut-producing countries, the industry may put more effort into producing the best quality oil rather than increasing the quality of the copra meal by-products. Various reports have identified that copra meal is of typically poor nutritional and feeding value when it was used as a feed ingredient in poultry diets. The poor quality of copra meal is due to its low concentration of several limiting amino acids (Creswell and Brooks, 1971; NRC, 1994; Sundu *et al.,* 2009), heat

© World's Poultry Science Association 2012

Received for publication December 18, 2011
Accepted for publication February 10, 2012

https://doi.org/10.1017/S0043933912000839 Published online by Cambridge University Press

damage during drying and oil extraction process (Butterworth and Fox, 1963) and high levels of dietary fibre (Knudsen, 1997; Sundu and Dingle, 2003; Sundu, 2008).

Although efforts have been made to improve the feeding value of copra meal through physical and enzymatic treatments (Sundu *et al.,* 2005) and fermentation (Hatta and Sundu, 2009), limited success has been achieved in improving its nutritive value to allow acceptable levels of body weight gain in poultry. Many of the results were far from the body weights expected from standard breed tables. Instead of focusing on improving its nutritive value, extracting mannans from copra meal is the other area that can be potentially useful as a feed additive. Sundu and Damry (2008) pioneered research into using beta-mannans from copra meal as a prebiotic to replace antibiotic growth promoters and as a mycotoxin binder, since mannan-oligosaccharides from yeast have been successfully used to improve performance and health status of birds for decades. Since then, several authors have reported the success of using CM in the diets of broiler chickens (Yamin, 2010; Fitryani, 2009). This paper reviews the potential use of CMs as either a prebiotic or a novel mycotoxin binder as compared to other similar products for broiler chickens.

Plant mannans

Southgate (1991) classified mannans as; 'reserve polysaccharides which are mainly the polymer of mannose, linked by either alpha or beta configuration'. Typically, mannans are encountered in different sub-families, depending upon the presence of other sugars in the polymer chain and these include pure mannan, galactomannan and glucomannan, and linkage configuration such as alpha and beta-mannan. Pure mannan is a polymer of mannose as it contains more than 95% mannose. The presence of galactose and glucose were reported in the side chain form in galactomannan and glucomannan respectively (Aspinal, 1970). Since the main component of these mannans is mannose, which forms the backbone of this carbohydrate, the term 'mannan' is widely used to refer to either galactomannan or glucomannan.

Mannans are found in legumes in the form of galactomannan. Mannan in legumes is made up of a chain of β (1-4) –D-manopyranose units to which the galactose residue attaches as a side chains of D-galactopyranose units (Kapoor *et al.,* 1998). A number of legume species have been reported to contain mannan, such as soybean (Jackson *et al.,* 1999), guar gum (Daskiran and Teeter, 2001) and locus bean (Kapoor *et al.,* 1998). Mannan is found in yeast as a major constituent of its cell wall. Mannan in yeast, particularly *Saccaharomyces cerevisiae*, possess a backbone of α-(1-6)-linked D-mannose units which are substituted by side chains containing (1-2)-and (1-3)-linked D-mannose units (Cawley and Ballou, 1972) while mannan in *Palmae spp.*, such as ivory nuts (Aspinal *et al.,* 1953), date nuts (Ishrud *et al.,* 2001), oil palm kernels (Daud and Jarvis, 1992) and coconut (Saittagaroon *et al.,* 1983), is composed of a chain of β (1-4) –D-mannopyranose units linked to a very small quantity of galactose units (Southgate, 1991; Kapoor *et al.,* 1998). The ratio of mannose to galactose units can affect the physico-chemical characteristics of these mannans when they are consumed by the chickens. The galactose units found in legumes can strongly bind water and make solutions (including intestinal contents) viscous, as found in guar gum and soybean meal with mannose to galactose ratios of 1.63 and 3.12 respectively (Kapoor *et al.,* 1998). Mannans in all forms, either homopolymer mannan, galactomannan or glucomannan, with either alpha or beta linkages, are considered indigestible as enzymes to break down these components are absent in the digestive tract of chickens, and mannans are insoluble in water (Aspinal, 1970; Southgate, 1991).

https://doi.org/10.1017/S0043933912000839 Published online by Cambridge University Press

Over the last few decades there has been a rapidly expanding interest in polysaccharides both in the application of non-starch polysaccharides as a source of carbohydrates for energy and as a feed additive for poultry. Among non-starch polysaccharydes studied, mannan has been a main focus of interest in nutrition, due to its unique function. Beta-mannan, which is commonly found in legumes and other plants, has been reported to have antinutrient properties (Jackson *et al.,* 1999) while alpha-mannan from *Saccharomyces cerevisiae* is believed to be a prebiotic (Newman, 1994) and mycotoxins binder (Devegowda *et al.,* 1997). Differences in chemical structure may be the cause of the difference in physiological properties when these materials are fed to broiler chickens. Studies on the effect of mannan and galactomannan have been carried out by a number of workers. The authors identified that mannans from guar gum and soybean meal can retard growth and decrease the efficiency of feed conversion in broilers (Ray *et al.,* 1982, Verma and McNab, 1982), inhibit insulin secretion in human (Morgan *et al.,* 1985) and inhibit water and glucose absorption in swine (Sambrook and Rainbird, 1985). However, yeast, particularly *Saccharomyces cerevisiae* that contains relatively high quantity of alpha-mannan (White *et al.,* 2002), has a binding capacity against pathogenic bacteria and mycotoxins and thus can be used as a feed additive in poultry diets. Therefore, it may be beneficial to identify alternative mannans which facilitate better growth, production and health of poultry birds.

Copra-mannans

Coconut or copra non-starch polysaccharides (NSP) have been studied intensively 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%). Previously, Rao and Bagchi (1961) had identified these two carbohydrate fractions in copra meal. A more recent study by Saittagaroon *et al.* (1983) demonstrated that mannan is the major polysaccharide in copra meal, as it represents 61% of the total polysaccharides, and the residue of alkali extraction contained mannose (42%) and glucose (58%). The presence of mannose and glucose found by Saittagaroon *et al.* (1983) can be interpreted as glucomannan or a mixture of mannan and cellulose. From these two studies it may be hypothesised that these substances were from cellulose and mannan, as their availability had been identified in a previous study by Balasubramaniam (1976), and neither Rao and Bagchi (1961) nor Balasubramaniam (1976) found the availability of glucomannan in the coconut meal. Supporting the finding of Saittagaroon *et al.* (1983), Dusterhoft *et al.* (1991) stated that mannan was the predominant NSP in coconut meal as intracellular compounds.

A study of Knudsen (1997) was able to comprehensively break down NSPs in copra meal into monosaccharides. Of the 42% NSP in coconut meal, most NSPs were water insoluble non-cellulosic polysaccharides. The coconut monosaccharides included arabinose, xylose, mannose, galactose and glucose (Knudsen, 1997) although they did not identify and quantify the kinds of possible NSPs. From the current understanding of monosaccharides residues in coconut meal, several NSPs can be predicted to be present, such as mannan, arabinogalactan and galactomannan. This prediction seems to be relevant to the finding of Saittagaroon *et al.* (1983) who reported the presence of mannan alongside small amounts of arabinogalactan, galactomannan, arabinomanogalactan and galactoglucomannan as previously mentioned by Knudsen (1997).

Kusakabe and Takashi (1988) extracted mannans from copra meal by using 24%

https://doi.org/10.1017/S0043933912000839 Published online by Cambridge University Press

NaOH. The residue found after the extraction was identified as mannan, as the analysis followed a similar procedure was used by Balasubramaniam (1976) who used 17% NaOH. Velasco and Meimban (1989) varied the concentration of NaOH to extract mannan from copra meal and found that among the extractants used, water was the poorest and the 18% solution of the NaOH extracted the highest total mannan, while the 4% solution ranked second. It seems that the higher concentration of NaOH in extracting CM was able to generate more mannan in the residue. Velasco and Meimban (1989) recommended to use 18% NaOH and even the use of a 24% solution, as used by Takashi and Kusakabe (1988), which may generate more mannans. Accordingly, Sundu and Damry (2008) extracted beta-mannan from copra meal by using the method of Kusakabe and Takashi (1988). The authors found that the concentration of CM (the leftover residue) was in the range of 29 and 34%. According to Velasco and Meimban (1989), factors affecting mannan concentration in coconut included the maturity of the nuts, along with the solvent concentration to extract beta-mannan. The concentration of CM found by Sundu and Damry (2008) was relatively high as compared to others feedstuffs *e.g.* 1.49 to 2.12% in soybean meal (Hsiao *et al.,* 2006) and 31% in yeast (White *et al.,* 2002).

CM in poultry diets

Since Sundu and Dingle (2003) questioned whether CM has the same properties as was found in guar and soybean meal, studies involving the inclusion of copra meal in broiler diets and its impact on viscosity of the jejunal digesta have been intensively conducted both in the University of Queensland, Australia and The University of Tadulako, Indonesia. It is apparent that CM has different properties in the way it behaves when it binds water. Physically, CM is hard and crystalline, and chemically, the mannose to galactose ratio is very high, being 14:1 (Kusakabe and Takashi, 1988). This is far above the mannose to galactose ratio found in guar, soybean and fenugreek. As CM has relatively high water holding capacity (Sundu, 2008), it may hold water more like sponge, and thus its viscosity is relatively low. Sundu *et al.* (2004) demonstrated that when copra meal was added in the diet, viscosity of jejunal digesta of broiler was not increased. There is no published data to justify CM being categorised as an antinutrient or a pronutrient. Hence, references that CM has an anti-nutritional properties is too simplistic and typically refers to mannan from guar, fenugreek and soybean.

The question to be addressed is whether CM can be used as a feed additive to promote growth in poultry feed. Several studies have confirmed that CM has the potential to promote growth. Yamin (2010) indicated that, when 0.05% CM was included in the diet, both the growth and feed efficiency of broilers was improved by 7% and 12% respectively. Feed digestibility of CM-supplemented diets was improved by 2.5% (Sundu *et al.,* 2010). More importantly, CM decreased the moisture content of faeces, as this continues to be a major commercial issue in poultry production. Problems associated with wet droppings are numerous, and include increased bacterial load in the litter, odour or ammonia in the house, insect problems, soiled feathers and footpad lesions (Butcher and Miles, 2011). Yamin (2010) pelleted diets containing CM to determine whether processing affects the efficacy of CM when included in the broiler feed. It was reported that pelleting did not impair the positive effect of CM in the diet since the body weight of birds was not negatively affected.

The mechanisms behind the improvement of body weight gain in birds fed CM-supplemented diets are not be clearly understood, and may be derived via several modes of actions. Firstly, addition of CM in the diet is associated with increased feed

https://doi.org/10.1017/S0043933912000839 Published online by Cambridge University Press

digestibility (*Table 1*). It is not difficult to elaborate the relationship between weight gain and feed digestibility as weight gain is a function of total digested feed and nutrient losses via faeces, urine and body heat. Secondly, CM may improve the health status of birds through the binding capacity of this carbohydrate against several pathogenic bacteria, such as *E. coli* (Fitryani, 2009). Thirdly, CM may bind mycotoxins (Sundu *et al.,* 2010) which can damage enzymes, particularly lipase (Matur *et al.,* 2010) and destroy the intestinal villi of birds (Applegate *et al.,* 2009) and this contribute to decreased nutrient uptake.

Table 1 Improvements in broiler performance due to CM supplementation used as a growth promoter.

Parameters	Increase (%)	Authors and years
Body weight gain	+ 7.4	Yamin (2010)
Feed Intake	+6.0	Yamin (2010)
FCR	-12	Yamin (2010)
DM digestibility	+2.5	Sundu *et al.* (2009)
Moisture content of faeces	-5.5	Sundu *et al.* (2009)
Caeca pH	-6.8	Sundu *et al.* (2010)
Abdominal fat	-6.1	Kannan *et al.* (2005)

CM as a replacement for antibiotic growth promoters

Mannose-based carbohydrates, either in the forms of mannosa (Oyofo *et al.,* 1989), mannan-oligosaccharides (Lyons, 2002) or mannan (Sundu and Damry, 2008) have been presented as choices to replace antibiotics due to their capacity to bind and flush pathogenic bacteria out of the digestive tract of poultry. The commercial use of mannan-oligosaccharides extracted from *Saccharomyces cerevisiae* has existed more than three decades, and the product is widely available in the market today. In comparison, the use of CM in replacing antibiotic growth promoters has only recently attained research attention, with initial work being conducted by Sundu and Damry (2008), which has been followed up by Yamin (2010) and Fitryani (2009).

A study carried out by Fitryani (2009) showed that when the birds were challenged with *E. coli* in their drinking water for a week, broiler body weight gain was adversely affected and moisture content of the excreta increased by 13%, due to diarrhoea being observed in many of the *E. coli* - challenged birds. The supplementation of feed with 0.05% CM reversed the problems of decreased body weight gain, wet droppings and the incidence of diarrhoea for the challenged birds. However, the concentration of immunoglobulin A in the blood was not improved due to CM supplementation in the challenged groups (Fitryani, 2009). A few voluminous reports indicated that the addition of yeast mannan-oligosaccharides in diets improved the immune status of the birds (Newman, 1994; de Lange, 2007). Speculation behind the findings of Fitryani (2009) has suggested that the shorter time of exposure to *E. coli* (7 days challenge) used in the trial may be the reason for unimproved immunoglobulin levels, either IgA or IgG.

A comparative study was conducted by Damry and Sundu (2009) to determine the efficacy of CM compared to commercial antibiotic growth promoters. The authors found that addition of CM in the diet improved growth rate to same level of body weight gain seen in birds fed diets supplemented either with commercial yeast mannan or avilamycin. It seems that these two mannan products posses similar efficacy of boosting the growth of broiler. Reasons of improved performance of birds due to the use of yeast mannan-

https://doi.org/10.1017/S0043933912000839 Published online by Cambridge University Press

oligosaccharides have been reviewed by other authors (Newman, 1994; De Lange, 2007). The reasons of improved bird performance due to CM supplementation are still unclear whether the improvement in body weight is due to CM in the diet *per se* or CM undergoes hydrolytic processes in the digestive tract of birds to form mannan-oligosaccharides or mannose through physical digestion in the gizzard or acid hydrolysis in the proventriculus. Since there is no specific enzyme to digest mannan in the digestive tract of birds, it can be speculated that formation of either mannan-oligosaccharides or mannose from CM may be low. This may explain why when Sundu and Damry (2008) used 0.02% CM, the improvement in body weight were statistically undetected and further increase in CM concentration in the diet to 0.05% produced significant improvement in body weight gain of broiler chickens.

Copra-mannan as a mycotoxin and cholesterol binder

Mycotoxins are produced by certain moulds and are defined as secondary metabolic products of *e.g. Aspergillus, Penicillium, Fusarium* and *Claviceps*. The numbers of mycotoxins that have been identified number about 300 different types to date, but it is predicted the total number is much more than this (Yiannikouris and Jouany, 2002). Of those mycotoxins, aflatoxins are more frequently found in the tropical regions, where the humidity and temperature suit the growth of mould, particularly *Aspergillus spp*. that produce aflatoxins. According to the FAO survey, 25% of the world's cereal grains are contaminated by mycotoxins (Devegowda and Murthy, 2005). From 17 samples analysed from China and 824 samples from India, reportedly 90% and over were contaminated with mycotoxins (Swamy, 2005). In Indonesia, 70% copra meal and 45% corn were contaminated by aflatoxins by more than 20 ppb (Sutikno, 1990). So the problem of mycotoxins in the feed industry is real and widespread and this problem represents the second major problem in the poultry feed industry, after the increased price of conventional feedstuffs.

Although there is no agreement on the safe level of aflatoxins in feeds, this mycotoxin affects all poultry species. Kermanshahi *et al.* (2007) and Devegowda and Murthy (2005) found decreased body weight gain when the birds were fed a diet containing 1.2 ppm and 2.5 ppm aflatoxin respectively. Since many factors can affect the negative effect of feeding Aflatoxin-contaminated feeds, including levels of aflatoxins, the presence of other mycotoxins and the duration of exposure, it is a general rule that growing poultry should not receive more than 20 ppb aflatoxin in the diet (Wyatt, 2005). Negative impacts of feeding mycotoxin-contaminated feed for poultry have been well reviewed by Devegowda and Murthy (2005). A number of organs in poultry are affected by mycotoxins, mainly the liver, kidney, mouth and digestive tract. Mycotoxins also impair feed quality and thus decrease feed intake, retarded growth and egg production, decrease activity of digestive enzymes (Matur *et al.,* 2010), decrease feed digestibility (Damry and Sundu, 2009), suppress the immune system and increase mortality (Elizabeth, 2005; Swamy, 2005).

In the sense of binding mycotoxins, yeast mannan has been reportedly to be a multi-mycotoxin binder, stable at high temperature over a wide range of pH and is considered environmentally friendly. Since the inclusion rate of this type of mycotoxin binder in the diet is relatively low, mixing it with the diet does not affect feed palatability and its does not bind other nutrients such as amino acids and vitamins (Hashmi *et al.,* 2000; Devegowda and Murthy, 2005). Although clays such as bentonite and aluminium silicate have been used for several decades to bind mycotoxins, this product has been reportedly effective for aflatoxins only, and it also binds other nutrients and needs to be

https://doi.org/10.1017/S0043933912000839 Published online by Cambridge University Press

included in relatively large quantity in the diet for efficacy (Chestnut *et al.,* 1992). The use of mannan, particularly yeast mannan, has been widely accepted in the feed industry.

Since there was some evidence that CM had the capacity to bind certain pathogenic microbes to the same degree as yeast mannan (Sundu and Damry, 2008), CM may also be able to bind mycotoxins. A study to examine this potential was conducted by Sundu *et al.* (2010). The results showed that inclusion of CM at a level of 0.3 ppm in an aflatoxin-contaminated diet maintained the growth of birds to the same level of birds fed either the uncontaminated control diet or 0.3 ppm aflatoxins-contaminated diets supplemented with a commercial yeast mannan. When the authors compared the efficacy of CM as a mycotoxin binder with other commercial mycotoxin binders such as yeast mannan and bentonite, the results were promising, in which body weight gain of birds fed the aflatoxins contaminated diets with CM addition, was slightly higher than those birds fed on aflatoxins contaminated diets either with yeast commercial mannan or bentonite. The findings of Sundu and Damry (2008) have indicated that CM can be affectively used as mycotoxin binders (see *Table 2*).

Table 2 Improvement of performance of bird fed 0.3 ppm aflatoxin B1 contaminated-diets (%) following the addition of different binders.

	Treatments		
Parameters	**CM**	**Yeast mannan**	**Bentonite**
Body weight gain (g)	+7.2	+5.1	+1.9
Feed intake (g)	-0.5	+0.2	+2.9
FCR	-7.3	-4.5	+1.1
DM faeces (%)	+26.1	+25.3	+24.5
DM digestibility (%)	+4.1	+4.0	+4.1
Protein digestibility (%)	+4.6	+3.6	+4.6

The use of mannan to decrease blood cholesterol level in poultry has been investigated by Vuksan and Vidgen (2001). Mannan has been reported to successfully lower total cholesterol level in the blood and, as a human food, may be related to lower incidence of heart attack. This fact motivated Kannan *et al.* (2005) to investigate whether CM could be used as a cholesterol binder in broiler feed. The use of 0.1% CM decreased total cholesterol and triglyceride levels from 197 mg/dl to 183 mg/dl and from 82.5 mg/dl to 59.3 mg/dl respectively, and reduced abdominal fat. Kannan *et al.* (2005) speculated that the decrease in either cholesterol or triglycerides was a result of increased populations of beneficial bacteria such as *Lactobacillus* or *Bacillus Subtilis* in the hind gut of poultry.

Since CM could reduce blood cholesterol of the birds, this mannan form may be used as an alternative to produce 'healthier' chicken meat. More studies are still needed to establish our understanding on CM by studying its mode of actions on how this product affects performance and health of birds. Work on quality control, extraction methods and consistency of this mannan is also needed to secure reliable performance responses in birds when used in the field or in large scale experiments.

References

APPLEGATE, T.J., SCHATZMAYR, G., PRICKET, K., TROCHE, C. and JI, Z. (2009) Effect of aflatoxin on intestinal function and nutrient loss in laying hens. *Poultry Science* **88**: 1235-1241.

https://doi.org/10.1017/S0043933912000839 Published online by Cambridge University Press

ASPINAL, G.O., HIRST, E.L., PERCIVAL, E.G.V. and WILLIAMSON, J.R. (1953) The mannans of ivory nut (Ptytelephas macrocarpa). I. The methylationof mannan A and mannan B. *Journal of the Chemical Society* (London) **Part III**: 3184-3188.

ASPINAL, G.O. (1970) *Polysaccharides.* Pergamon Press, New York.

BALASUBRAMANIAM, K. (1976) Polysaccharides of the kernel of maturing and mature coconuts. *Journal of Food Science* **41**: 1370-1373.

BUTTERWORTH, M.H. and FOX, A.C. (1963) The effect of heat treatment on the nutritive value of coconut meal and the prediction of the nutritive value by chemical methods. *British Journal of Nutrition* **17**: 445-452.

BUTCHER, D. and MILES, R.D. (2011) Causes and preventions of wet litter in broiler houses. IFAS Extention, University of Florida.

CAWLEY, T.N. and BALLOU, C.E. (1972) Identification of two Saccharomyces cerevisiae cell wall mannan chemotypes. *Journal of Bacteriology* **111**: 690-695.

CHESTNUT, A.B., ANDERSON, P.D., CHOCHRAN, M.A., FRIBOURG, H.A., and GWINN, K.D. (1992) Effects of hydrated sodium calcium aluminosilicate on fescue toxicosis and mineral absorption. *Journal of Animal Science* **70**: 2838-2846.

CRESWELL, D.C. and BROOKS, C.C. (1971) Compositions, apparent digestibility and energy evaluation of coconut oil and coconut meal. *Journal of Animal Science* **33**: 366-369.

DAMRY, H.B. and SUNDU, B. (2009) Ekstrak beta-mannan dari kelapa (cocos nucifera L) sebagai pengganti antibiotik pada unggas. *Laporan penelitian Fundamental*, Untad, palu.

DASKIRAN, M. and TEETER, R.G. (2001) Effect of endo-ß-D-mannanase (Hemicell[@]) supplementation on growth performance of two week -old broilers fed diets varying in betha mannan content. Animal Science Research Report. Accessed 24 February 2009.

DAUD, M.J. and JARVIS, M.C. (1992) Mannan of oil palm kernel. *Phytochemistry* **31**: 463-464.

DE LANGE, L.L.M. (2007) Adding Bio-Mos to broiler breeder diets and to starter diets for broiler chickens improves breeder and broiler performance, hatchability, economics and immune status. *Proceedings of Alltech's 23 rd Annual Symposium*. Eds: T.P. lyons, K.T. Jacques and J.M. Hower. Nottingham University Press, Nottingham, UK. pp:123-130.

DEVEGOWDA, G. and MURTHY, T.N.K. (2005) Mycotoxins: Their effects in poultry and some practical solutions, in: DIAZ, D.E. (Ed.) *The Mycotoxins Blue Book*, pp. 25-26 (Nottingham Press, United Kingdom).

DEVEGOWDA, G., ARAVIND, B.I.R. and MORTON, M.G. (1997) Immunosuppression in poultry caused by aflatoxins and its alleviation by Saccharomyces cereviseae (Yea-Sacc 1026) and manno-oligosaccharydes (Mycosorb), in: LYONS, T.P. & JACQUES, K.A. (Eds) *Biotechnology in the Feed industry,* pp: 2015-216, Proceeding of Alltech's 13th annual symposium..

DUSTERHOFT, E.M., VORAGEN, G.J. and ENGELS, F.M. (1991) Non-starch polysaccharide from sunflower (Helianthus annuus) meal and palm kernel (Elaeis guineensis) meal preparation of cell wall material and extraction of polysaccharide fractions. *Journal of the Science of Food and Agriculture* **55**: 411-422.

ELIZABETH, S. (2005) Mould growth and mycotoxin production, in: DIAZ, D.E. (Ed.) *The Mycotoxins Blue Book*, pp. 225-234 (Nottingham Press, United Kingdom).

FITRYANI (2009) Ekstrak beta-mannan dari bungkil kelapa (Cocos nucifera L) sebagai pengganti beta-mannan komersial dan anti biotic untuk meningkatkan kesehatan ayam broiler. *Thesis*, Universitas Tadulako, Palu, Indonesia.

HASHMI, I., PASHA, T.N., JABBAR, M.A., AKRAM, M. and HASHMI, S. (2000) Study of adsorption potential of yeast sludge against aflatoxins in broiler chicks. *Journal of Animal and Plant Science* **16**: 12-14

HATTA, U. and SUNDU, B. (2009) Improving quality of copra meal by fermentation. *The first International seminar on Animal Industry*, Bogor, IPB. Indonesia, pp: 101.

HSIAO, H.Y., ANDERSON, D.M. and DALE, N.M. (2006) Levels of B-mannan in soybean meal. *Poultry Science* **85**:1430-1432.

ISHRUD, O., ZAHID, M., AHMAD, V.U. and PAN, Y. (2001) Isolation of structure analysis of a glucomannan from the seeds of Libyan dates. *Journal of Agriculture and Food Chemistry* **49**: 3772-3774.

JACKSON, M.E., FODGE, D.W. and HSIAO, H.Y. (1999) Effects of ß-mannanase in corn soybean meal diets on laying hen performance. *Poultry Science* **7**: 1737-1741.

KAPOOR, V.P., TARAVEL, F.R., JOSELEAU, J.P., MILAS, M., CHANZY, H. and RINAUDO, M. (1998) Cassia spectabilis DC seed galactomannan: structural, crystallographic and rheological studies. *Carbohydrate Research* **306**: 231-241.

KANNAN, M., KARUNAKARAN, R., BALAKRISHNAN, V. and PRABHAKAR, T.G. (2005).Influence of prebiotics supplementation on lipid profile of broilers. *International Journal of Poultry Science* **4**: 994-997.

KERMANSHAHI, H., AKBARI, M.R., MALEKI, M. and BEHGAR, M. (2007) Effect of prolonged low level inclusion of aflatoxin B1 into diet on performance, nutrient digestibility, histopathology and blood enzymes of broiler chickens. *Journal of Animal and Veterinary Advances* **6**:686–692.

KNUDSEN, K.E.B. (1997) Carbohydrate and liginin contents of plant materials used in animal feeding. *Animal Feed Science Technology* **67**: 319-338.

https://doi.org/10.1017/S0043933912000839 Published online by Cambridge University Press

KUSAKABE, I. and TAKASHI, R. (1988) Enzymatic preparation beta 1-4 mannooligosaccharides and beta 1-4 gluco-mannooligosaccharides. *Methods in Enzymology* **160**: 518-523.

LYONS, T.P. (2002) Navigating from niche markets to mainstream: A feed industry kakumei. In *Proceedings of Alltech's 16th Annual Asia - Pacific Lecture Tour.* Alltech.

MATUR, E., ERGUL, E., AKYAZI, I., ERASLAN, E. and CIRAKLI, Z.T. (2010) The effects of *Saccharomyces cerevisiae* extract on the weight of some organs, liver, and pancreatic digestive enzyme activity in breeder hens fed diets contaminated with aflatoxins. *Poultry Science* **89** :2213-2220

MORGAN, L.M., TREDGER, J.A., MADDEN, A., KWASOWSKI, P. and MARKS, V. (1985) The effect of guar gum on carbohydrate, fat and protein stimulated gut hormone secretion: modification of postprandial gastric inhibitory polypeptyde and gastrin responses. *British Journal of Nutrition* **53**: 467-475.

NRC (1994) *Nutrient Requirements of Poultry.* National Academy Press, Washington, DC.

NEWMAN, K. (1994) Mannan-oligosaccharides: natural polymers with significant impact on the gastrointestinal microflora and the immune system. *Proceedings of Alltech's 10th Annual Symposium.* Eds: T.P. lyons, and K.T. Jacques Nottingham University Press, Nottingham, UK. pp:123-130.

OYOFO, B.A., DELOACH, J.R., CORRIER, D.E., NORMAN, J.O., ZIPRIN, R.L. and MOLLENHAUER, H.H. (1989) Prevention of Salmonella-typhimurium colonization of broilers with D-mannose. *Poultry Science* **68**: 1357-1360.

RAO, C.V.N. and BAGCHI, P. (1961) A water soluble galactomannan from coconut (Cocos nucifera). *Canadian Journal of Chemistry,* **39**: 375 -381.

RAY, S., PUBOLS, M.H. and MCGINNIS, J. (1982) The effects of purified guar degrading enzyme on chick growth. *Poultry Science* **61**: 488-494.

SAITTAGAROON, S., KAWAKISHI, S. and NAMIKI, M. (1983) Characterisation of polysaccharides of copra meal. *Journal of the Science of Food and Agriculture* **34**: 855-860.

SAMBROOK, I.E. and RAINBIRD, A.L. (1985) The effects of guar gum and level and source of dietary fat on glucose tolerance in growing pigs. *British Journal of Nutrition* **54**: 27-35.

SUNDU, B. (2008) The apparent metabolizable energy and amino acid digestibilities of copra meal in Broiler diets. *Journal Agripet* **8**: 16-20.

SUNDU, B. and DINGLE, J. (2003) Use of enzymes to improve the nutritive value of palm kernel meal and copra meal. *Queensland Poultry Science symposium* **11**:1-15.

SUNDU, B., KUMAR, A. and DINGLE, J. (2004) The effects of levels of copra meal and enzymes on bird performance. *Proceedings of Australian Poultry Science symposium* **16**:52-54.

SUNDU, B., KUMAR, A. and DINGLE, J. (2005) Growth pattern of broilers fed a physically or enzymatically treated copra meal diet. *Proceedings of Australian Poultry* Science *Symposium* **17**: 291-294.

SUNDU, B. and DAMRY, H.B. (2008) Ekstrak beta-mannan dari kelapa sebagai pengganti antibiotik untuk unggas. Laporan penelitian Fundamental, Untad, palu.

SUNDU, B., HATTA, U. and DAMRY, H.B. (2010) Ekstrak beta-mannan dari kelapa sebagai pengikat mikotoksin pada unggas. Laporan penelitian Fundamental, Untad, palu.

SUNDU, B., KUMAR, A. and DINGLE, J. (2009) Feeding value of copra meal for broilers. *World's Poultry Science Journal* **65**: 481-491.

SUTIKNO, A.I. (1990) Screening of aflatoxin in duck feedstuffs in west java , Indonesia. *Journal of the Science of Food and Agriculture* **50**: 459-465.

SOUTHGATE, D.A.T. (1991) *Determination of Food Carbohydrates.* Elsevier Science, New York.

SWAMY, H.V.L.N. (2005) Mycotoxicoses in Poultry: an overview from the Asia Pacific region. In: Nutritional Biotechnology in the feed and food industry. *Proc. Alltech's 21 Annual symposium*. Editors: Lyons, T.P and Jacques, K.A. Nottingham Press, United Kingdom, pp: 75-89

VELASCO, J.R. and MEIMBAN, J. (1989) Studies on coconut SAPAL . III. Mannan in the developing nut. *Philippine Journal of Coconut Studies* **14**: 23-25.

VERMA, S.V.S. and MCNAB, J.M. (1982) Guar meal in diets for broiler chickens. *British Poultry Science* **23**: 95-105.

VUKSAN, V. and VIDGEN, E. (2001) Effects of Viscous dietary fibre from kojac mannan in subjects with the insulin resistance syndrome. *Diabetes Care* **23**: 9-14.

WHITE, L.A., NEWMAN, M.C., CROMWELL, G.L. and LINDEMAN, M.D. (2002) Brewer's dried yeast as a source of mannan oligosaccharides for weanling pigs. Journal of Animal Science **80**: 2619-2628.

WYATT, R.D. (2005) Mycotoxin interactions, in: DIAZ, D.E. (Ed.) *The Mycotoxins Blue Book*, pp. 269-278 (Nottingham Press, United Kingdom).

YAMIN, M. (2010) Pengaruh bentuk fisik ransum yang mengandung beberapa pronutrisis terhadap performans ayam pedaging. *Thesis*, Universitas Tadulako, Palu, Indonesia.

YIANNIKOURIS, A. and JOUANY, J.P. (2002) Mycotoxins in feed and their fate in animals: a review. *Animal Research* **51**: 81-89.

https://doi.org/10.1017/S0043933912000839 Published online by Cambridge University Press

https://doi.org/10.1017/S0043933912000839 Published online by Cambridge University Press