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EFFECT OF *Morinda citrifolia* IN GROWTH, PRODUCTION AND IMMUNOMODULATORY PROPERTIES IN LIVESTOCK AND POULTRY: A REVIEW

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ABSTRACT

Morinda citrifolia L. is commonly known as Noni and has been found to have wide range of medicinal properties. It is usually found in the coastal region in many countries including Andaman and Nicobar Islands and belongs to the family *Rubiaceae*. This small evergreen tree is widely grown and well adapted to the tropics and can grow in fertile, acidic, alkaline and saline affected soils. It tolerates high soil salinity and brackish water stagnation. All the components of this plant have high demand in case of alternative medicines and herbal medicines. Due to its high demand and as a source of revenue generation the detail study on its nutritional benefits and therapeutic values are essential for its commercial exploitation. More than 200 nutraceutical compounds have been identified from the plant. *Morinda citrifolia* is reported to have broad spectrum biological activities such as antimicrobial, immunomodualtory, antioxidant wound healing etc. Apart from the *in-vitro* scientific validation of the activities and *in-vivo* trial in some lab animal model, the plant has been used for livestock and poultry health and production. A lot of reviews have been written on the different uses of Noni, however, scientific review on the use of this plant on the growth, production, immunomodulator and other pharmacological activities of *M. citrifolia* in livestock and poultry has not been compiled. Therefore this review discusses the compilation of the work done on the use of *M. citrifolia* in livestock and poultry.

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1 Introduction

Livestock farming is considered to be a profitable complementary enterprise in agriculture and constitutes an important activity for accelerating the rural economy. They are being reared under small open ranging system to large scale intensive system in our country. This sector has been growing at steady pace; however, during the recent years due to indiscriminate usages of antibiotics in livestock and poultry the problem of multidrug resistance has evolved (Woolhouse et al., 2015). The high dosage of antibiotics, hormones and chemical derivatives for increase and sustain livestock production has increased the problem of its residual effects in their products thus causing a serious health concern (Landers et al., 2012). The organic farming has changed the scenario of the present agricultural production system; similarly the concept of organic livestock production system has been evolved. The use of traditional medicine and alternative medicine has been practiced by the farmers for sustainable production (Galav et al., 2013; Luseba & Tshisikhawe, 2013).

A large number of medicinal plants with known medicinal properties are available and is being used by the farmers (Chinsembu et al., 2014; Verma, 2014; Luseba & Tshisikhawe, 2015). *Morinda citrifolia* is also known as Noni, belongs to the family Rubiaceae and is mostly available in the coastal region (Nelson, 2006). It is commonly known as Indian mulberry, Ba Ji Tian, Nono or Nonu, Cheese fruit and Nhau in various countries throughout the world (Bruggnecate, 1992; Whistler, 1992; Solomon, 1999; Chan-Blanco et al., 2006). In these islands it is commonly known as Lorang, Burmaphal, Pongee phal and Surangi by the tribal. *M. citrifolia* has a rich history in India, where it has been used for tens of centuries in the system of medicine known as Ayurveda. This small evergreen tree or sprint (10-20 ft) is native to India and also distributed to south-eastern Asia to Australia and now has tropical distribution widely adapted to the tropics (Dixon et al., 1999; Ross, 2001). It can grow in challenged environments viz, saline, acidic and alkaline soils. M. citrifoia has been known for its wide range of medicinal properties (Younos et al., 1990; Bruggnecate, 1992; Hiramatsu et al., 1993; Hirazumi et al., 1996; Solomon, 1999; Brown, 2012; Assi et al., 2015). Reports are available on the scientific studies of this plant and wide health benefits. The plant is also suitable for saline affected lands, owing to its saline resistant properties the plant can be gown as an alternative crop for the saline affected areas and its high demand both at national and international market, the studies on its phytochemicals and its effect on production and immune response is utmost importance.

Polynesians used the whole plant for treatment of various kinds of illness as herbal remedies (Earle, 2001). Various reports are available for use of this plant for treatment of illness such as diabetes, blood pressure, cancers, arthritis, poor digestion etc. (Singh et al., 1984; Bruggnecate, 1992; Solomon, 1999; Whistler, 1992; Wang et al., 2002; Brown, 2012; Lee et al., 2012; Fletcher et al., 2013; Saminathan et al., 2013a; Saminathan et al., 2014b; Sharma et al., 2016). However, there is less information on the scientific validation of the Morinda fruits viz. treatment of colds and influenza reported by Solomon, 1999. Allen (1873) reported some information on the ethno botanical properties, which is considered to be one of the earliest report on the medicinal use of morinda.

The history of use of *M. citrifolia* for livestock and poultry is very limited. Due to its strong smell and taste many animals do not consume the product and avoid contact with the fruit and seeds. The residents of South Pacific islands have noted health benefits for themselves and their animals by ingesting the *M. citrifolia* fruit (Whistler, 1985). Some animals such as pigs consume the fruit in its natural state (Fugh-Berman, 2003). Most animals have difficulty in consuming and digesting whole fruit. The available literatures revealed that the leaves are used for livestock fodder (eg. Niue, India) and to feed silk worms (India). Over the year's research have been mainly carried out on use of fruit and leaf extract. Studies have been carried out on anthelmintic property (Raj, 1975; Morton,1992), anti-inflammatory (Basar et al., 2010; Fletcher et al., 2013), antitumor potential (Hirazumi & Furusawa, 1999; Furusawa, 2002; Brown, 2012; Jinhua et al., 2013; Saminathan et al., 2014a), utilization of its juice extract waste in diets of goats (Aregheore, 2005), enhanced mononuclear phagocytic activity of gram-negative bacteria in calves fed with the fruit puree (Schafer et al., 2008). Researchers have been carried out on the volatile components of ripe fruits and their effects on drosophila (Farine et al., 1996). Studies on the effect of its fruit and leaf extract in the total serum protein, creatinine and albumen level of poultry have been carried out (Sunder et al., 2011a). However, the scientific evidence of its use in animal model and its effect on production system is very rare (Fugh-Berman, 2003; Sunder et al., 2007; Sunder et al., 2011b; Sunder et al., 2011b c). In the present review, information on the available literature on the use of *M. citrifolia* in livestock and poultry has been documented.

2 Growth and production promoting properties in poultry

The growth performance ability of the *M. citrifolia* fruit was tested in Nicobari fowl; an indigenous poultry bird of Andaman & Nicobar Islands, India and broiler (Sunder et al., 2011b). Broilers were given fresh noni fruit juice (1.5 ml/bird/day). The performance of the morinda fed group was found more than the control birds in terms of body weight gain, feed conversion ratio and feed efficiency. The overall performance index of Morinda fed group was found to be superior (93.6±16.15) than other groups. Egg production was also recorded to be high in the morinda fed group (95.24%) than in control (83.11 %). Similarly, highest dressing % was obtained in the Morinda fed group (69.05%) than in control (68.38%). The highest body weight gain during the 3rd and 4th month of age was observed due to the growing phase of the bird during which the bird attained more body weight gain than compared to the other phase of the growth. The reports of Morinda on the growth was reported by Sunder et al. (2007) in

broiler birds, however, no reports are available on the effect on the egg production in the Nicoabri fowl.

Studies on feeding of *M. citrifolia* fruit extract to Japanese quail showed better body weight gain, feed conversion ratio and performance index in Morinda fed group than in control group. The overall results revealed that higher body weight gain in Morinda fed group (162.11±0.06 g) compared to control group (153.005±1.05 g) for 0 to 7 weeks of age. FCR of the Morinda fed group (5.99 ± 0.17) was recorded better than control group (6.18 ± 0.16). The feed efficiency of Morinda fed group (0.22 ± 0.05) was also found to be higher ($p<0.05$) than control group (0.20±0.08). The hen day egg production was recorded better in the Morinda fed group when compared to the control group. The overall analysis of the growth and production performance of both the groups revealed that the *M. citrifolia* crude fruit extract fed @ 5% daily enhanced the body weight gain and the egg production performance of the Japanese quail (Sunder et al., 2013d).

3 Growth, production and imunomodulatory properties in livestock

Ethno veterinary application of noni fruit puree has been studied in the livestock. Brooks et al. (2009) demonstrated that feeding of noni puree enhanced the immunity of neonatal calves and potentially long term health especially in the preweaning stage. In earlier findings, Brooks et al. (2009) reported that supplementation of juice from *M. citrifolia* enhanced the activation of CD4+ and CD8+ T cells in neonatal calves. Bactericidal effect of noni was evaluated via an ex vivo whole blood bactericidal assay by Schäfer et al. (2008). Result showed that noni fed group showed significantly more killing power at day 14 when compared to control calves. Advantages of supplementing Morinda Max have been demonstrated in newly received cattle. Yancey et al. (2013) studied the growth performance effect of feeding of noni in cattle. They have reported that feeding of pulp of *M. citrifolia* to cow at the level of up to 2% in the diet increased body weight gain with better feed conversion ratio. The gain was increased with the increase in concentration of Noni pulp in the diet. Ponce et al. (2011) found that feeding of Noni extract to calf increased the growth performance as well as the immunomodulatory properties. The immune enhancing effect including the antibacterial, anti-inflammatory, anti cancer and anti oxidant effect of noni has been validated (Pawlus et al., 2005; Kusirisin et al., 2009; Nitteranon et al., 2011). Presence of Iridoid and polysaccharide fractions of noni has been shown to induce the release of several immune mediators, many of which have beneficial stimulatory effects and may help in the maturation of the neonatal immune system (Bui et al., 2006; Hirazumi & Furusawa, 1999; Deng et al., 2010).

The growth promotion effect of *M. citrifolia* juice may be due to its rich nutrients value which contain all the essential amino acids, minerals, vitamins and other nutrients which are required for the growing cells (Chunhieng, 2003) It is very rich in proxeronine which is believed to be a precursor to xeronine which helps in activation of xeroninase (Heinicke, 2001). As the Morinda fruit contain several amino acid, vitamins, minerals, co-enzymes, carbohydrates and alkaloids which directly or indirectly help in metabolism of the nutrients and help in overall growth of the cell and tissues (Chan Blanco et al., 2006; Takashima et al., 2007; Assi et al., 2015). More than 200 nutraceutical compounds have been identified from the plant (Solomon, 1999; Singh, 2012). Leaf and fruit of this plant are reported to be used as feed for livestock and poultry (Fugh-Berman, 2003). However, further investigation on several bioactive compounds present in the M. ciirifolia will help in understanding the actual mechanism in detail and its use in livestock and poultry as a source of vitamins and minerals supplement for higher growth, production and immunity.

3.1 Anticholesterol properties

Cholesterol is very important compounds used for many physiological functions; however, the unwanted increase in the level of bad cholesterol is the predisposing factors for many of the diseases. Lot of works have been carried out to lower the level of cholesterol in chicken meat by using addtivies, feed supplents, etc. (Chowdhury et al., 2002; Yalcin et al., 2006; Aydin et al., 2008; Azeke & Ekpo, 2009; Saki et al., 2014). Considering the importance of the cholesterol content the study was conducted to see the effect of *M. citrifolia* fruit and leaf extract supplementation on the blood cholesterol level. A group of 100 poultry birds were fed 5% crude fruit extract and leaf extract of *M. citrifolia* daily along with the normal basal ration. Studies on borilers and Nicobari fowl revealed that feeding of fruit extract (5%) and leaf extract (5%) daily along with the normal basal ration lowered the blood cholesterol level. The cholesterol level in the Morinda fruit extract fed group at 4th week (179+12.3) and at 6th week (201+9.4) was found to be lower than control group (185+11.4) and (233+10.5), respectively. The cholesterol level in the birds fed with leaves extract was found to be slightly higher than fruit extract. The cholesterol level in the Morinda leaf extract fed group at 4th week were (190±11.1) and at 6th week were (210±5.4) was again found to be lower than the control group (222±12.3) and (248±8.1) respectively. The result revealed that the feeding of M. citrifoiia extract daily in the poultry ration has lowered the level of cholesterol in the blood serum (Sunder et al., 2011a). Reports suggest that the Noni has phytochemicals and beta-sitosterol, a plant sterol with potential for anti-cholesterol activity (Palu et al., 2006; Wang et al., 2006). Research on lowering the cholesterol level in chicken meat and egg is going on worldwide. Research showed that cholesterol content may vary in eggs and blood and lot of work is being carried out on chicken eggs and meat either through the use of additives, dietary fibre, polyunsaturated fatty acids supplementation etc (Barroeta, 2007; Dalkilic et al., 2009). Recent study showed that feeding of morinda fruit extracts to calves reduced the level of total cholesterol, triglycerides, LDL-cholesterol in the morinda fed group than in the control group (Anantharaj et al., 2016).

3.2 Effect on blood biochemcial profile of poultry

Concentration of serum protein is useful in monitoring various disease status. It increases during dehydration, multiple myeloma and chronic liver diseases, and decreases in renal diseases and liver failure. Creatinine is a waste product formed in the muscle from the high energy storage compound creatinine phosphate. It is useful indicator of renal function and increases in various renal diseases. Albumin is a plasma protein synthesized in liver from amino acids absorbed from ileum. It increases during dehydration and stasis during venipuncture. It decreases during excess protein loss and decreases synthesis due to dietary, hepatic disease or malabsorbtion (Babatunde et al., 1992). Lot of reports are available on the effect of feeding of herbal plants and its extracts on the blood biochemical profile of poultry, (Langhout, 2000; Kamel, 2001; Elagib et al., 2012; Hosseinzadeh et al., 2014; Kant et al., 2014). However, very few researches have been carried out to see the effect of feeding of noni in the blood biochemical profile of poultry. Sunder et al., 2011a found that feeding of noni decreases the level of total protein, serum creatinine and albumin in the poultry. There is no report available on the effect of *M. citrifolia* in blood biochemical parameters of poultry, however, similar to this study, Polat et al., 2011 found that feeding of rosemary reduces the blood cholesterol level and increases the creatinine level. Creatinine is a chemical waste molecule that is generated from muscle metabolism. The lower values indicates that no muscular wastage which might have been possibly cause by inadequacy of protein in animals. In the present study also the level of blood protein was found to be low. However, Ghazalah & Ali (2008) found that creatinine levels were all reduced by dietary rosemary leaves compared to controls. It is useful indicator of renal function and increase in various renal diseases. Albumin is synthesized in the liver from amino acids absorbed from the ileum. It increases during dehydration and decreases during excess protein loss. The level of total serum protein, albumin and creatinine was found to be better in the Morinda fed group. The effect of *M. citrifolia* on various biochemical parameters may be useful in monitoring physiological status and disease status as well as therapeutic evaluation of the products. Research showed that the feeding of *M. citrifolia* juice enhanced the immune response in poultry (Sunder et al., 2007).

3.3 Antimastitis properties in cattle

Mastitis is a serious problem of the dairy cows and estimated loss due to direct and indirect looses has been estimated to the tune of $35 billion annually (Mubarack et al., 2011). Infection of the cow's udder and the mastitis is considered as one of the major constraints for growth of dairy industry worldwide (Sasidhar et al., 2002; Osteras & Solverod, 2009). Due to development of multidrug resistance bacteria the use of herbal based preparation for treatment of mastitis and other diseases have been reported in livestock (Virmani et al., 2010; Kalayou et al., 2012; Mir et al., 2014; Zeedan et al., 2014). Several plants have been reported to be used for treatment of mastitis viz. Capsicum annuum, Lepidium sativum, Allium sativum, Sesamum indicum, Citrus limon, Zingiber officinale, Citrullus colocynthis, Curcuma longa, Amomum subulatum, Sesamum indicum, Cuminum cyminum, Rosa indica, Centratherum anthelmisticum, Triticum aestivum, Nigella sativa and Peganum harmala (Dilshad et al., 2009). In many of the reports, the antibacterial activity of the plant extracts were described against the organisms responsible for mastitis, however, Sunder et al. (2013a) reported the treatment of mastitis by feeding of *M. citrifolia* in dairy cows. Sunder et al. (2013a) observed that oral feeding of noni fruit juice (100 ml) to dairy cows is effective for treatment of mastitis. In the mastitis milk, level of electrical conductivity increases due to changes in ionic concentration which resulted in the decrease in the level of lactose and K+ and increase in the level of Na+ and Cl (Kitchen, 1981; Kaşikçi et al., 2012). Sunder et al. (2013a) found that feeding of *M. citrifolia* decreased the electrical conductivity from 5.5 mho to less than 5.0 mho, which resulted in decrease in the milk pH (7.0 to 6.6) thus reducing the total microbial load in the milk. Level of microbial load was also decreased from 5.13 x 108 to 3.54 x108. Among the normal cow no change was observed in the pH of cow's milk with respect to different teat of the cow (Batavani et al., 2007). In case of mastitis Electrical conductivity will vary in the range of 5.58 mS. It is concluded that the feeding of *M. citrifolia* reduced the milk pH, electrical conducti8vity, microbial load in the mastitis affected milk.

4 *M. citrifolia* as feed supplement

Plants are being used as a source of feed and feed additives in animal feeding since time immemorial. During the recent years due to ban of most of the antibiotic growth promoters use of medicinal plants as a feed additives, supplements for the livestock and poultry have been increased (Charis, 2000; Tipu et al., 2006 ; Mirzaei-Aghsaghali, 2012; Eevuri & Putturu, 2013; Mirzaei & Venkatesh, 2012). Use of *M. citrifolia* fruit as a feed ingredient was studied in Japanese quail (Sunder et al., 2013b,d). *M. citrifolia* fruits were cut into small pieces and sun dried. The dried fruits were grounded to make it in the form of small granules. Fruit granules were added in the quail ration up to 15% by replacing maize, rice bran and wheat by 5% each. The body weight at 2nd, 3rd and 5th week of age was higher significantly ($p<0.05$) in the Morinda fed group compared to the control group. Feed conversion ratio and egg production was found to be better in morinda fed group. The overall production performance revealed that at the end of 100 days of egg production the Morinda fed group showed 24% more egg production than the control group. The study showed that *M. citrifolia* can be used as feed ingredient in Japanese quail ration to the tune of 15% on dry matter basis. In an another study, Japanese quail were fed with fruit granules of *M. citrifolia*, 20% (w/w) as replacement of the normal concentrate mixture in the ration (Sunder et al., 2013 b). Results revealed the higher body weight gain in morinda group (109.4±7.22) than in control group (106.8±6.65) at 5th week of age. Egg production was also found better in morinda group (59.34±12.31) than in control group (56.80±10.71). It is

concluded that part-replacement of quail ration with dried ripe fruit granules of *M. citrifolia* (20%, w/w) would be cost-efficient in quails with no apparent side effects. This is the first report of use of *M. citrifolia* fruit granules as feed supplement in the poultry. There is no report available on the use of *M. citrifolia* fruit pulp as a feed for poultry. However, some reports are available on the use of leaf and fruit of this plant as feed for livestock and poultry (Fugh-Berman, 2003). Use of other medicinal plants viz. Curcuma longa, turmeric, Ocimum sanctum, tulsi, Aloe vera, were also reported to enahcned the body weight gain, better FCR, feed efficiency in poultry (Kumar et al., 2005; Durrani et al., 2006; Lanjewar, 2008; Al-Kassie et al., 2011; Eevuri & Putturu, 2013). The proximate analysis of the noni fruit pulp revealed that the crude protein content is only 5.8%, however, it is very rich in all amino acids, micro and macro minerals and vitamins which are essential for the vital functioning of the cells/tissues for growth and production. The *M. citrifolia* fruit is very rich in the nutraceutical compounds and contains rich amounts of minerals like K, Ca, Mg, Fe, Cu and Mn (Singh et al., 2008). High egg production and growth promoting effect may be due to the nutraceutical compounds and minerals present in the fruit which might have played important role in enhancing the growth and production. The earlier reports with the use of *M. citrifolia* fruit juice revealed that the supplementation of *M. citrifolia* juice @ 5% enhanced body weight gain in broiler and Japanese quail (Sunder et al., 2007, Sunder et al., 2011a). Morinda fruit contain several amino acids, vitamins, minerals, co-enzymes, carbohydrates and alkaloids which directly or indirectly help in metabolism of the nutrients and help in overall growth of the cell and issues hence in the Morinda fed group the overall performance was better than in control group. The studies on evaluation and utilization of Noni juice extract waste (NJEW) in goat's diet revealed that the unusual taste and low degradability of essential nutrients may be the factors limiting the use of NJEW in ruminant diets. Therefore, research on its palatability quality is required so that the extracts and the fibres may be effectively utilized as a source of livestock food (Aregheore, 2005)

5 *M. citrifolia* as Immunomodulator

Immune system of poultry generally benefits from the medicinal plants and herbs which are rich in flavonoids, vitamin C and carotenoids. During the last decade there has been substantial increase in the use of medicinal herbs as feed supplement, immunostimulant and growth promoters. Many plants are available which are very rich in these compounds including the *M. citrifolia*. There are several reports available with the use of medicinal herbs for immunostimulants in the poultry (Kumari et al., 1994; Emadi & Kermanshahi, 2007; Durrani et al., 2008; Lee et al., 2010; Mahima et al., 2012; Mirzaei-Aghsaghali , 2012; Dhama et al., 2015). Phytochemical analysis of the *M. citrifolia* revealed the presence of several compounds viz. carbohydrates, gums and mucilages, proteins, amino acids, fats and oils, anthraquinone glycosides, coumarin glycosides, flavonoids, alkaloids, tannins, phenolic compounds and citric acid which are responsible for several activities including the immunostimulation (Nayak et al., 2012). Studies showed that *M. citrifolia* stimulated the immune system for anti tumor, anticancer, antioxidant activities both in-vivo and in-vitro (Hirazumi & Furusawa, 1999; Furusawa & Hirazumi, 2003; Palu et al., 2006; Nayak & Mengi, 2010; Mufidah et al., 2013; Assi et al., 2015; Krishnaiah et al., 2015). However, very few reports are available on the use of *M. citrifolia* as imnomostimulant in livestock and poultry (Sunder et al., 2007; Lohani, 2010; Sunder et al., 2011a; Benjamin et al., 2014). Studied showed that feeding 5% crude leaf extract of *M. citrifolia* to Nicobari fowl enhanced B cell mediated immune response. Furusawa et al. (2003) studied the antitumor activity in allogeneic mice and found that immunomodualtory property is due to a polysaccharide rich substance present in the fruit. Sunder et al. (2007) also studied the immunomodulatory properties of *M. citrifolia* in poultry. This was the first report of immunomodulaotry properties of *M. citrifolia* in poultry. They found that feeding of *M. citrifolia* fruit juice @ 5% in water enhanced both humoral (B cell mediated) and cellular (T cell mediated) immunity in broilers. The humoral immune response of the Morinda group was significantly better than control group ($P<0.05$). The peak response was observed at first week post inoculation (PI) in Morinda group (1.48±0.18) compared to control group (0.82±0.1). The direct challenge test of IBDV in the Morinda fed birds showed protection against the infection as only 6.6% mortality was recorded in this group compared to 25% in control.

Humoral immunity and cell mediated immunity of *M. citrifolia* was studied by Sunder et al. (2011b) and found that supplementation of 1.5 ml of fruit juice enhanced B cell and T cell mediated immunity in Nicobari fowl. Literatures also indicated that Noni increases the defences and reinforces the immune system of the body, neutralize its function in all the cells and regenerates the affected cells (Heinicke, 1985). Thus it helps in preventing the diseases such as IBDV infection in the present study as it increases the immune response as observed. Reports also suggests the effect of *M. citrifolia* in inducing the release of interferons, interleukins and nitric oxide (Hirazamu & Furusawa,1999).

6 Synergistic effect of Morinda with other medicinal plant and probiotic

During the last decade lot of works have been carried out in search of alternative to antibiotics which could be safely used as growth promoter, antimicrobial without any side effect or residual compounds in the end products. Probiotics are single or mixed group of bacteria when administered to the host showed many beneficial effects viz. growth promotion, enhancing nutrient uptake from the intestine, reducing the harmful microorganism, increases the immunity (Kabir, 2009; Brisbin et al., 2010). Reports are available on the use of lactobacillus as growth promoter and probiotics in livestock and poultry (Ibrahim et al., 2005; Salarmoini & Fooladi, 2011; Zamanzad-Ghavidel et al., 2011). Similarly, beneficial proprieties of medicinal plants have also been reported in the

the livestock and poultry by many workers (Mishra et al., 2008; Javed et al., 2009; Narimani-Rad et al., 2011). Use of probiotics and prebiotics together showed beneficial effect showed that However, Sunder et al. (2012) and Sunder et al. (2015) studied the use of combination of Morinda and lactobacillus in poultry. They reported that combination of *M. citrifolia* and lactobacillus showed synergistic effect in terms of body weight gain, immunomodulatory properties, and reduction in gut microbial count and feed efficiency. This is the only report available on the combined use of *M. citrifolia* and lactobacillus in poultry.

Since the ban of antibiotics as growth promoters in poultry, the use of lactobacillus and herbal based nutraceuticals compounds have been increased. Role of nutraceuticals in improving the gut health and growth performance of poultry have been described by many workers (Muir et al., 2000; Yang et al., 2009; Zamanzad-Ghavidel et al., 2011; Adil & Magray, 2012; Das et al., 2012; Fallah et al., 2013; Sugiharto, 2015). However, Sunder et al. (2015) studied the feeding of noni and lactobacillus sin broiler which was not studied earlier. They found that feeding of lactobacillus and noni juice showed synergistic effect and enhanced the reduction in gut coliform load. Antimicrobial activity of *M. citrifolia* was also reported by some workers and they found that the activity is mainly due to presence of terpenoid compounds, phenolic compounds such as acubin, alizarin, acopoletin, anthraquinones in the noni fruit (Jin et al., 1998; Lavanya & Brahmaprakash, 2011; Narimani-Rad et al., 2011; Salarmoini & Fooladi, 2011).

Histology study of the chicken gut after feeding with noni fruit and lactobacillus showed significant changes in crypt depth and villi height, which is considered to be the main site for development of immune response and nutrient uptake (Sunder et al., 2014a). Similar to the finding of use of noni and lactobacillus, use of herbal based feed supplement as a growth promoter and effect on the gut function has also been reported by some workers (Hashemi et al., 2009; Lavinia et al, 2009; Abdulkarim et al., 2013; Kanduri et al., 2013).

7 *Morinda citrifolia* and Andrographis paniculata on expression of toll-like receptors

Kalmegh (Andrographis paniculata) a promising medicinal plant has been scientifically validated to exhibit functions such as antiinflammaotry, immunomodulator (Sheeja & Kuttan, 2007; Abu-Ghefreh et al., 2009; Wang et al., 2010; Shen et al., 2013; Gao & Wang, 2016). Toll like receptors (TLRs) are innate immune receptors and induce fast and appropriate host defence reaction against pathogens. TLRs recognise the conserved microbial patterns such as flagellin, LPS, peptidoglycan in an efficient and non self reactive manner to initiate pro inflammatory cytokines. Role of TLR in the immunomodulation has been demonstrated and at least 10 TLRs have been identified in chickens, including TLR1A, 1B, 2A, 2B, 3, 4, 5, 7, 15 and 21 (Barjesteh et al., 2013; St Paul et al., 2013). Sunder et al. (2014b) studied that supplementation of Noni and Kalmegh influenced the expression levels of TLR-2, TLR-3, TLR-4, TLR-5, TLR-15 and TLR-21 significantly ($P<0.05$). The gene expression level of TLR-3, TLR-4 and TLR-5 was found more which showed the immunomodulatory properties of herbal extract. The increased expression of TLR-3, TLR-4 and TLR-5 may be due to the effects of phytochemicals on these TLR signal transduction pathway. Andrographolide has been found to induce the APK and PI3K signaling pathway which thereby involved in macrophage activation (Rao, 2001; Fukao & Koyasu, 2003; Wang et al., 2010). Park et al. (2009) also found that production of interferon is mainly due to the presence of quercetin in the noni fruit. This was also supported with the finding of Tanabe et al., 2003 and Tohyama et al., 2005. They also found that IFN-γ plays important role in expression of TLR-3, TLR-4 and TLR-5. The high level of TLR-3, TLR-4 and TLR-5 and decreased TLR-7 gene indicated the antiviral and antibacterial activities.

In another study the effect of feeding of *M. citrifolia* fruit to broiler was done and expression of TLR-4, TLR-5, IL-8, and IL-12 was found to be more while the TLR-7 and IL-6 level was lowered. The high level of interleukins and TLR may be responsible for antiviral and antibacterial activities in the noni fruits.

8 Grommune tonic for poultry

Feeding of Grommune, a noni based herbal tonic showed more body weight gain, better FCR and enhanced B cell mediated immunity in broilers. The dose was standardized and found that feeding of Grommune @ 15 ml per bird up to 4 week and 30 ml per bird up to 8th week of age improved the body weight, feed conversion ratio and immune competency status of broilers (Sunder et al., 2014c).

9 Morical supplement for Japanese quail

Sunder et al. (2013b,c) studied the feeding of different concentration of morical, a herbal based *M. citrifolia* feed supplement in the Japanese quail. They found that supplementation of 4% (w/w) of morical in feed showed more annual egg production (238.5) compared to control (215.4). They also observed that egg shell thickness, high Ca content in egg shell, egg yolk content, total weight of the egg increased with the increasing concentration of morical supplementation up to 8% in the feed.

10 Anticancer Activity

Antitumor activity of the noni fruit was reported due to the presence of a polysaccharide rich substance (Hirazumi et al., 1994). Reports also suggests the role of *M. citrifolia* as anticancer and antitumor properties (Liu et al., 2001; Wang et al., 2001; Wang & Su, 2001; Wong, 2004; Issell et al., 2009; Brown, 2012; Saminathan et al., 2013a; Wu et al., 2015). Later, a lot of studies were carried out to find out the compounds responsible for the antitumor and anticancer activities directly or indirectly (Hiramatsu et al., 1993; Hisawa et al., 1999; Hirazumi & Furusawa, 1999; Mathivanan et al.,

2005). Studies on effect of Noni-ppt showed impvoemnt in the survival time and curative effect in treatment of cancer. Noni-ppt administration significantly prolonged the survival duration of inbred Lewis lung tumor-bearing mice (Hirazumi et al., 1996). Further studies on Noni-ppt suggested that it suppress the tumor growth through release of TNF- , IL-1ß, IL-10, IL-12 p70, IFN- , and nitric oxide (Hirazumi & Furusawa, 1999). Some individual compounds from Noni juice were reported to function as ras inhibitors and thus suppressed the ras-expressing tumors (Wang et al., 1999).

Liu et al. (2001) found that the antitumor potential of noni fruit due to the presence of glycosides and asperulosidic acid extracted from the noni fruit on the AP-1 transactivation and cell transformation in mouse epidermal JB6 cells. They found that both the compound suppressed the cell transformation and AP-1 activity.

Wang & Su (2001) found that supplementation of noni juice to rats helped in prevention of DMBA-DNA adduct formation by 30% in heart, 41% in lung, 42% in liver, and 80% in kidney. Arpornsuwan & Punjanon (2006) tested the methanol extract from *M. citrifolia* fruits for cytotoxicity activity on the MTT assay. The appearance of cytotoxic changes after exposure to the extract was in a concentration dependent manner. The most sensitive cell line was baby hamster which showed median lethal concentration of 2.5 mg/ml followed by Vero cell (3.0 mg/ml) and human laryngeal carcinoma cell (5.0 mg/ml) respectively.

In another study, Thani et al. (2010) found the cytotoxic activity of noni leaves against the KB cell line while Lv et al. (2011) found the anticancer potential in the root extracts. Gupta & Patel (2013) also demonstrated that combination of Noni and cisplatin were able to induced the anticancerous activity through the p53 and Bax proteins (pro-apoptotic) up regulating pathways and Bcl-2 (anti-apoptotic gene), survivin and Bcl-XL proteins down regulating mechanisms. Saminathan et al. (2013b) showed the antitumor activity of noni fruit against mammary tumours in rats. The frequency of the tumor incidence was found to be significantly decreased in the noni fruit treated group and only benign tumour was observed while in the control group malignant tumour was observed.

11 Hypotensive activity

The first report of the hypotensive potential of the noni fruit was available in 1927, when Davison (1927) found that hot water extract of noni roots lowered the blood pressure of dog, the study was supported by the finding of Youngken et al., 1960; Youngken, 1958; Gilani et al., 2010. Later, Moorthy & Reddy (1970) and Yamaguchi et al. (2002) also reported the hypotensive effect of ethanol extract of noni dogs and rats respectively. Asahina et al., 1994 showed the diueretic effect of noni fruit juice.

12 Anti-inflammatory activity

The first scientific validation of the anti-inflammatory activity of noni juice was reported by Zhang et al. (1994). They studied the inhibitory activity of noni juice on COX-2 and COX-1 activities and compared with traditional anti-inflammatory drugs such as aspirin, indomethacin and celebrex. They found that activity of noni in COX-2 inhibition was on par with the celebrex. Later, Wang et al. (2002) also studied the anti-inflammatory activity of noni juice and found that feeding of 10% noni juice in drinking water for 12 days decreases the inflammatory foci in and acute liver injury model in female rats induced by the CCl4. McKoy et al. (2002) showed that feeding of 200 mg of *M. citrifolia* prevented the formation of paw edema in the rats. This anti-inflammatory effect may be due to the inhibition of B2 receptor mediated mechanism of bradykinin

Study showed that damnacanthal isolated from the *M. citrifolia* roots mediates anti-inflammatory activity through H1 receptor (Okusada et al., 2011). Dussossoy et al. (2011) reported that the anti-inflammatory activity of the noni is due to the presence of several polyphenols, flavonoids, phenolics compounds, irridoids and ascorbic acid. These compounds probably acts through the NO and PGE2 pathways by directly inhinbiting the cycloxygenase COX-1 and COX-2 activities.

Palu et al. (2006) also described the use of noni seed oil as anti-inflammatory activity in skin. Noni seed oil inhibited the COX-2 and 5-LOX enzymes in a concentration dependent manner and found that it is safe for topical use for skin care applications and is non-comedogenic.

13 Analgesic effect

The analgesic potential of M. ctirifolia was reported by Younos et al. (1990). They evaluated the root extracts of *M. citrifolia* in mice and found that it showed a dose-related analgesic activity in the writhing and hot plate tests in mice. The extract did not show any toxic effect and further, on administration of higher dose, it decreased all the behavioural parameters and induces sleeping which is suggestive of sedative properties of the *M. citrifolia*. The analgesic and tranquilizing properties of the noni fruit was also reported by Joseph Betz (1997) and Wang et al. (2002). They also observed the dose dependant analgesic properties of the M.citrifolia in mice.

Punjanon & Nandhasri (2005) evaluated the different dose concentration of noni fruit extract viz. 1, 2, 3 and 4 g in mice and compared with the morphine sulphate. They found that 4 g/kg-1 concentration of noni fruit extract showed similar effect as produced by the morphine sulphate in inhibition of abdominal constriction induced by acetic acid.

This proves that *M. citrifolia* is having analgesic effect; however, detail studies are necessary for the identification of the chemical compounds and to study the mechanism of action. The analgesic efficacy of alcoholic extracts of Noni fruits was also demonstrated in the acetic acid induced writhing test (Okusada et al., 2011). In another study, Basar et al. (2010) demonstrated the analgesic activity of alcohol extract of noni fruit in reducing the pain and arthritis.

14 Antimicrobial Activity

Many reports are available on the antimicrobial activity of *M. citrifolia*. Atkinson, 1956 reported that the antibacterial effect of noni is due to the presence of acubin, L-asperuloside, alizarin and anthraquinone. Reports also suggested that these compounds are responsible for antibacterial activity against Ps. Aeruginosa, Pr. Morgaii, B. subtilis, S. aureus, E. coli, Shigella and Salmonella as well as treatment of skin infection, cold fever and other bacterial infection (Bushnell et al., 1950; Tabrah & Eveleth, 1966; Leach et al., 1988; Locher et al., 1995). Duncan et al. (1998) showed that scopoletin, a compound available in the noni is responsible for antibacterial activity against E. coli and control of serious illness and even death. Umezawa (1992) demonstrated that anti HIV activity in the noni is due to the presence of a compound i.e 1-methoxy-2-formyl-3-hydroxyanthraquinone which suppressed the cytopatheic effect of HIV infected cells.

Broad spectrum antibacterial activity of various solvent extracts of M. ctirifolia have been reported against Gram positive and Gram negative microorganisms (Wei et al., 2008; Jayaraman et al., 2008; Selvam et al., 2009; Kumar et al., 2010; Usha et al., 2010; Sunder et al., 2012; West et al., 2012).

The first report of the use of noni against tuberculosis was demonstrated by Saludes et al. (2002). They demonstrated that bactericidal activity of the noni leaf extracts was 89% compared to 97 % with rifampicin. The antifungal activity of *M. citrifolia* was demonstrated by Banerjee et al. (2006). They studied the antifungal activity in-vitro and found that *M. citrifolia* inhibited the growth of C. albicans in-vitro. They also found that the same extract also showed inhibitory activity against Apergillus nidulans spores. Sunder et al. (2012) have studied the wide spectrum antibacterial and antifungal activity of various parts of the *M. citrifolia* extracts. They have found that the methanol, ethanol, ethyl acetate, chloroform, acetone extracts of leaf, stem bark, fruit and seed showed broad spectrum antibacterial and antifungal activity in – vitro.

Conclusion and future perspectives

Farmers in several countries use medicinal plants in the maintenance and conservation of the healthcare of livestock. The last two decades have seen tremendous interest in the area of medicinal and aromatic plants. The role of plant derived drugs have been emphasized both national and international level. Based on the findings of the several researches on the use of *Morinda citrifolia* for livestock health and production, it is concluded that the *M. citrifolia* may be used as alone or in combination with probiotics and other medicinal plants for growth, production, immunomodualtor, antioxidant and many other properties in livestock and poultry. A lot of compounds with neturaceutical values have been identified from the *Morinda citrifolia*. Although lot of products are available in the market for human use, however, there are are plenty of scope for development of noni based herbal products for livestock health and production. The antibacterial potential of the plant should be explored and studied in detail to develop the drug against multidrug resistance bacteria mainly for the tuberculosis, malaria, HIV and other diseses. The feeding of noni fruit has been found to exhibit very good antioxidant, anti-cholesterol and growth and immunomodulatory property in livestock and poultry. Study on the palatability fo the fruit should be carried out to develop the cheap and best technology which is available at the famer doorstep for the livestock and poultry. Reports suggested that chicken, duck and pig consumes the raw fruit of noni. However, the palatability of the fruit should be improved for feeding as such to the other livestock which could save the production losses and post harvest losses. The high mineral richness of the fruit and leaf should be studied in detail to study the efficacy of mineral supplement in poultry and large animals.

Since the ban of antibiotics as growth promoters by the European Union in 2006, lot of compounds, products etc have been studied as alternative to the antibiotics for probiotic, prebiotic, growth promotion effects in livestock and poultry. The presence of rich nutracrutical compounds in the noni might be useful for exploring this plant as an alternative to the antibiotic in poultry without giving any side effect. *Morinda citrifolia* trees are widely grown in coastal forest areas of A&N Islands. Owing to its high nutritive value for medicinal importance and having national and international market, increasing demand, there is a possibility for emerging as one of the most remunerative fruit crops to the island farmers. Recently, it has undergone a revival in Andaman and Nicolas Island as interest in plant with nutracentical properties has increased. Noni plant is distributed in almost all parts of the Island. It can be found near the coast, in open lands and Grassland, in gulches and in distributed forest of the dryer areas.

It tolerates high soil salinity and brackish water stagnation. All the components of this plant have high demand in case of alternative medicines and herbal medicines. Due to its high demand and as a source of revenue generation the detail study on its effect on the livestock health and production should be carried out for its commercial exploitation.

Conflict of interest

Authors would hereby like to declare that there is no conflict of interests that could possibly arise.

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