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Influence of stage of ripening and dietary concentration of Noni (*Morinda citrifolia* L.) powder on broiler performance

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Abstract

Phyto-additives in poultry diets enhance growth, feed efficiency and product quality and minimise the possible risk of residues from chemical additives. There are reports on the use of noni (*Morinda citrifolia*) fruit powder as phyto-additive in poultry diets but information on the effect of fruit ripening is scanty. Hence, this study compared the effect of unripe and ripe noni fruit powder on broiler performance. A control diet without and 4 diets containing two levels (0.25 and 0.5 %) unripe and ripe fruit powder were fed to 5 replicates containing 6 Cobb500™ broilers in a completely randomized design. Data collection was on growth performance, nutrient digestibility, and carcass and organ measurements. In the starter (8–21 d), feed intake (FI) reduced on 0.5 % unripe powder ($p < 0.05$) but did not differ between the control and 0.25 % ripe powder ($p > 0.05$). Nitrogen retention reduced on 0.25 % unripe powder compared to the control and the ripe powder ($p < 0.05$). Poorer dressing percentage was observed on 0.5 % ripe powder ($p < 0.05$). Breast weight was increased and thigh weight reduced on 0.25 % ripe and 0.5 % unripe powder ($p < 0.05$). In conclusion, up to 0.5 % noni, fruit powder has no beneficial effect on broiler growth, but the stage of ripening may influences protein digestibility and dressing percentage. We recommend more research into feed processing and diet composition.

Keywords: chemical feed additives, nutrient utilisation, phyto-additives, poultry, stage of maturity

1 Introduction

Several alternatives additives including probiotics, prebiotics and medicinal plant extracts are increasingly receiving attention in poultry nutrition due to increasing public health concerns with the use of chemical additives in animal feeds (Yamashita *et al.*, 2009; Jelveh *et al.*, 2018). Extracts from herbs and shrubs are reported to stimulate growth, improve poultry health and product quality (Mishra *et al.*, 2008; Javed *et al.*, 2009; Narimani-Rad *et al.*, 2011; Mirzaei-Aghsaghali, 2012; Mirzaei & Venkatesh, 2012; Eevuri & Putturu, 2013).

Morinda (*Morinda citrifolia*) generally known as noni grows wild or cultivated in humid tropical environments (Noni plant with fruits in Figure 1). In Fiji, although some farmers may grow noni for export, the crop grows mainly in the wild with no food value. This coupled with its exceptional adaptation to the local climate make the fruit locally available for inclusion in poultry diets by farmers in the country. In Asian countries, noni fruit and leaves are traditional foods (West *et al.*, 2006; Morton, 1992 cited in Diarra *et al.*, 2019). Noni has antibacterial, anticoccidial and anti-stress properties but little food value in most regions due to its poor taste (Hong *et al.*, 2019). There are reports on the use of noni fruit as a feed supplement for livestock and poultry (Sunder *et al.*, 2011, 2013a; Santoso & Fenita, 2017) but studies on the effect of stage of ripening on the utilisation of noni fruit by poultry are limited. Considering the compositional changes in noni products with stage of ripening (Yang *et al.*, 2011), this study investigated the efficacy of unripe and ripe noni fruit powder as supplement in broiler diets. We hypothesised that broilers will not respond to dietary unripe and ripe noni fruit powder similarly.

2 Materials and methods

2.1 Preparation of noni powder

Noni fruits (unripe and ripe) were harvested separately, chopped into pieces and oven-dried at 60 °C for 48 hours

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and ground to pass through a 2 mm sieve to obtain noni fruit powder. Powders from the unripe and ripe fruits were labelled as unripe and ripe powder, respectively.

Fig. 1: *Morinda citrifolia plant with fruit.*

2.2 *Experimental diets*

Five diets were formulated to meet the requirements of Cobb500™ broiler starter and finisher (Table 1). The control (basal) diet contained no noni fruit powder. The test diets contained two levels (0.25 and 0.5 %) of the unripe and ripe noni fruit powder each. All the diets were prepared as mash.

2.3 *Experimental site, birds and management*

The study was conducted at Mr. Jaiwant Pratap farm in Nasori, Fiji from 30 April to 14 June 2019. One hundred and sixty day-old Cobb500™ broiler chicks, purchased from Pacific Feed Ltd, Fiji, were brooded together, on deep litter with wood shavings as litter material, for 7 days during which they received the commercial starter diet. On day eight, 150 chicks were weighed individually (247 ± 7.5 g) and allotted to 15 floor pens (220 x 110 cm) with wood shaving as litter material. Each of the five diets was fed to birds in three replicate pens in a completely randomized design. Feed and clean water were provided ad libitum throughout the experimental period (starter 8–22 days; finisher 23–42 days). The research committee of the University of the South Pacific approved the experimental protocol.

2.4 *Data Collection*

Data were collected on growth performance (feed consumption, weight gain and feed conversion ratio), carcass measurements and nutrient digestibility. Feed supplied and left over were weighed to account for the quantity consumed. Birds were weighed at the start and end of the experiment and weight gain calculated by difference. Feed conversion ratio (FCR) was calculated per pen as the ratio of feed consumed to weight gained for each group. At 35 d, three birds randomly selected per treatment (1 bird per replicate) were housed in metabolism cages (60 x 30 x 30 cm) for seven days for apparent nutrient digestibility studies by total excreta collection method. The cages were located in an open-sided pen at ambient temperature 25–28 °C. The birds were adapted to the cage condition for the first 3 days followed by excreta collection. Feed intake (FI) was monitored through the last 4 days and all excreta collected and air-dried. Dried excreta from each replicate were pooled and ground to obtain homogenous samples. Feed and excreta samples were analysed for proximate composition (AOAC, 1995) and apparent nutrient digestibility calculated as:

Apparent digestibility (%)

$$= \frac{\text{Nutrient intake} - \text{Nutrient in faeces}}{\text{Nutrient intake}} \times 100$$

At the end of the experiment (42 d), one broiler weighing closest to the mean of the pen was selected from each replicate (3 birds per treatment) for carcass measurements. After 12 hours fasting, with water available ad-libitum, the birds were euthanised by cervical dislocation and scalded in hot water (about 57 °C for 2 minutes), plucked, eviscerated and dressed. The hot carcass and some cuts (thighs, drumstick and breast) were expressed as percentages of the live weight of the bird.

2.5 *Statistical analyses*

Data were analysed for variance (ANOVA; Steel & Torrie, 1980) of the GLM in SPSS (SPSS for Windows, version 22.0; IBM Corp., Armonk, NY, USA). Individual birds were the experimental units for carcass measurements and cages for nutrient digestibility. Pens were the experimental units for feed intake and weight gain. The Least Significant Difference (LSD) was used to compare treatment means and significant differences reported at 5 % level of probability.

3 Results

3.1 *Growth performance*

The growth performance results of the broilers are presented in Table 2. During the starter phase (8–22 d) feed intake was reduced on the unripe powders and 0.5 % ripe powder ($p < 0.05$). With the exception of FI, no significant differences were found between treatments for all the variables measured during all growth phases ($p > 0.05$).

Table 1: *Ingredient composition of broiler diets (%, as fed basis).*

	Starter diets (fed from day 8 to day 22)					*Finisher diets (fed from day 23 to day 42)*				
	control	*unripe powder*		*ripe powder*		*control*	*unripe powder*		*ripe powder*	
		0.25	*0.5*	*0.25*	*0.5*		*0.25*	*0.5*	*0.25*	*0.5*
Ingredients (%)										
Crushed maize	14.3	14.3	14.2	14.3	14.2	18.7	18.7	18.7	18.7	18.7
Crushed wheat	22.5	22.5	22.5	22.5	22.5	27.8	27.8	27.8	27.8	27.8
Wheat bran	7.1	6.82	6.5	6.82	6.5	9.0	9.0	9.0	9.0	9.0
Pea meal	37.1	37.1	37.1	37.1	37.1	28.4	28.4	28.4	28.4	28.4
Fish meal	9.3	9.3	9.3	9.3	9.3	4.02	4.02	4.02	4.02	4.02
Copra meal	5.82	5.85	6.02	5.85	6.02	8.2	7.95	7.7	7.95	7.7
Premix*	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
HCl-Lysine	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
DL-Methionine	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Salt	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Enzyme	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Coral Sand	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Noni	0	0.25	0.5	0.25	0.5	0	0.25	0.5	0.25	0.5
Analysis (%)										
Crude protein	21.0	21.5	22.0	21.2	21.0	19.2	18.9	18.8	19.0	18.7
Crude fibre	4.3	4.3	4.3	4.3	4.3	4.7	4.7	4.7	4.7	4.7
Crude fat	2.9	2.9	2.9	2.9	2.9	3.4	3.4	3.4	3.4	3.4
Phosphorus	1.0	1.1	0.8	0.9	1.1	0.8	0.8	0.8	0.7	1.0
Calcium	5.7	5.6	5.8	5.6	5.6	5.6	5.3	5.3	5.6	5.3
ME† (MJ/kg)	13.3	13.3	13.3	13.3	13.3	13.4	13.4	13.4	13.4	13.4

* Premix (Vitamin and mineral) Bio-mix supplied/kg diet, vitamin A: 10,000 IU, vitamin D3: 2,000 IU, vitamin E: 23 mg, niacin: 27.5 mg, vitamin B1: 1.8 mg, B2: 5 mg, B6: 3 mg, B12: 0.015 mg, vitamin K: 3.2 mg, pantothenic acid: 7.7 mg, biotin: 0.06 mg, folic acid: 0.75 mg, choline chloride: 300 mg, cobalt: 0.2 mg, copper: 3 mg, iodine: 1 mg, iron: 20 mg, manganese: 40 mg, selenium: 0.2 mg, zinc: 30 mg, anti-oxidant: 1.25 mg.
† ME: Metabolisable Energy.

Table 2: *Performance of broilers fed two levels of unripe and ripe noni fruit powder at different stages of growth.*

Diets	*8–22 d*			*23–42 d*			*8–42 d*		
	FI (kg)	*WG (kg)*	*FCR*	*FI (kg)*	*WG (kg)*	*FCR*	*FI (kg)*	*WG (kg)*	*FCR*
Control	23.8[a]	13.2	1.80	38.5	20.3	1.90	62.3	33.5	1.86
GP (0.25 %)	22.3[b]	11.9	1.87	37.9	23.3	1.63	60.2	35.2	1.71
RP (0.25 %)	23.6[a]	12.7	1.86	40.2	23.8	1.69	63.8	36.5	1.75
GP (0.5 %)	22.6[b]	12.5	1.80	38.8	22.2	1.75	61.4	34.7	1.77
RP (0.5 %)	23.1[b]	12.6	1.83	39.6	22.9	1.73	62.7	35.5	1.77
SEM	0.425	0.467	0.283	1.103	1.007	0.192	1.233	1.183	0.140
p value	0.012	0.777	0.911	0.616	0.680	0.422	0.334	0.938	0.775

FI: feed intake; WG: weight gain; FCR: feed conversion ratio.
GP: green or unripe noni powder; RP: ripe noni powder; SEM: standard error of the mean.
a, b: means in the column with same letter are not different at $p = 0.05$.

3.2 Nutrient digestibility

The results of nutrient digestibility of the broilers are presented in Table 3. Dry matter (DM) and ether extract (EE) digestibility were not affected by the diet ($p > 0.05$). Nitrogen retention was significantly reduced on the 0.25 % unripe noni powder compared to the control and ripe powder sup-

Table 3: *Nutrient digestibility of broilers fed two levels of unripe and ripe noni fruit powder.*

Parameters (%)	*Treatments*						
	Control	*GP 0.25 %*	*RP 0.25 %*	*GP 0.5 %*	*RP 0.5 %*	*SEM*	*p value*
DM	75.73	78.19	78.69	77.05	74.91	1.354	0.305
Ether extract	64.26	53.57	67.78	50.70	48.06	10.003	0.580
Nitrogen retention	62.63^{a}	52.74^{b}	63.81^{a}	54.72^{ab}	63.87^{a}	2.798	0.042

GP: green or unripe noni powder; RP: ripe noni powder; SEM: standard error of the mean.
a, b: means in the row with same letter are not different at $p = 0.05$.

Table 4: *Relative weight of carcass and cuts of broilers fed two levels of unripe and ripe noni fruit powder.*

Parameters (% live weight)	*Treatments*						
	Control	*GP 0.25 %*	*RP 0.25 %*	*GP 0.5 %*	*RP 0.5 %*	*SEM*	*p value*
Carcass	71.57^{a}	71.85^{a}	71.95^{a}	75.60^{a}	68.61^{b}	2.122	0.312
Breast	14.25^{b}	16.47^{b}	19.88^{a}	18.08^{a}	16.71^{b}	0.858	0.011
Thigh	14.10^{a}	13.09^{a}	11.60^{b}	12.60^{ab}	13.68^{a}	0.454	0.022
Drumstick	10.74	11.02	10.81	10.37	10.48	0.397	0.789

GP: green or unripe noni powder; RP: ripe noni powder; SEM: standard error of the mean.
a, b: means in the row with same letter are not different at $p = 0.05$.

plemented groups ($p < 0.05$). Nitrogen retention did not differ between the unripe powder fed birds and among those on the control, ripe powder and 0.5 % unripe powder ($p > 0.05$).

3.3 Carcass traits

The results of carcass studies (Table 4), showed significant dietary effects on the relative weights of carcass, breast and thigh muscles ($p < 0.05$). Carcass weight was markedly decreased ($p < 0.05$) on the diet containing 0.5 % ripe powder. Breast weight was improved on 0.25 % ripe and 0.5 % unripe powder ($p < 0.05$) compared to control, 0.25 % unripe and 0.5 % ripe powder. A lower thigh weight was recorded on 0.25 % ripe and 0.5 % unripe compared to the control, 0.25 % unripe powder and 0.5 % ripe powder ($p < 0.05$). The yield of drumsticks was not affected by dietary treatment ($p > 0.05$).

4 Discussion

4.1 Growth performance

The reduced feed intake on the 0.25 % unripe noni powder and subsequent improvement on the 0.25 % ripe powder was not clear but palatability problems due to possible compositional changes with fruit ripening may be speculated. The composition of noni fruit is reported to change with the stage of maturity (Millonig *et al.*, 2005; Motshakeri & Ghazali, 2015). Motshakeri & Ghazali (2015) reported increases in phenolic content of noni fruit from the green to white hard and a decrease from the white hard to the ripe soft stages. The ripe fruits used in the present study were harvested before softening to avoid the fruit going bad during drying. Although the experimental powder was not analysed for phytoconstituents due to lack of analytical facilities, possible differences in the composition of ripe fruit could be a possible reason for the pattern of feed intake as earlier mentioned. Feed intake was reduced at 0.5 % green (unripe) or ripe noni fruit powder in the diet. Several constituents identified in noni fruit, including anthraquinones, are known to exert antinutritional effects at high concentrations (Shalan *et al.*, 2016). These authors observed toxicity and high mortality in mice consuming 2 mg noni fruit extract per ml water and attributed this to the anthraquinones content of the fruit. This may explain the reduction in feed intake above 0.25 % dietary noni fruit powder. In another study, Flees *et al.* (2017) found no effects of 0.2 % dietary dried noni fruit powder on feed intake in heat stressed broilers. Supplementation of the diet with noni fruit extract at 1.5 ml/bird/day improved feed utilisation in broilers compared to the control (Sunder *et al.*, 2011). Improved feed intake and feed conversion ratio were reported in Japanese quails fed diets containing 15 % noni fruit granules as replacement for maize (Sunder *et al.*, 2013b). Sunder *et al.* (2007) also observed improved feed utilisation of Japanese quails receiving 0.5 % noni fruit extract in the diet. These authors used the ripe fruit powder or extract. Several factors including the stage of maturity, method of processing, the species and age of poultry and composition of the basal diet may affect the utilisation of noni fruit products by poultry. Although not analysed in the present study, it could be speculated that the nutritive quality of the fruit increases with stage of maturity. The fruits used in the present study were oven-dried fruits at 60 °C for 48 hours. The effect of heat on the composition of the powder may also be a possible factor in the results obtained. Despite the reduced feed intake during the starter phase, weight gain and feed conversion ratio were not affected by dietary noni fruit powder probably due to slightly higher protein content in the starter diet, resulting in better growth during this phase. There was no effect of noni powder inclusion on feed intake and growth performance during the finisher and overall growth phases suggesting that age may not be an important factor in the utilisation of noni powder by broilers with regard to weight gain and feed conversion.

4.2 Nutrient digestibility

Nitrogen retention was depressed on the diet containing 0.25 % green powder and subsequently improved on 0.25 % ripe and diets containing higher inclusion (0.5 %) of green or ripe powder. This trend of digestibility may be attributed to the lower concentration of phytochemical in the green powder on one hand and the changes in concentration with fruit maturity on the other hand. Currently, there are limited reports on the effect of noni products on nutrient digestibility. Improved feed utilisation of broilers (Sunder *et al.*, 2011) and Japanese quails (Sunder *et al.*, 2013b) with noni fruit extract supplementation may be the result of improved nutrient digestion. The findings of the present study suggest that at lower dietary concentrations, the ripe fruit is more effective in improving protein digestibility.

4.3 Carcass traits

Despite the reduced protein digestibility on the 0.25 % unripe powder, there was no difference in dressing percentage between this group and the control, 0.25 % ripe and 0.5 % unripe powder fed groups. The relative weights of carcass and breast muscle depressed on the 0.5 % ripe powder despite the improved nitrogen retention. These trends could not be explained but probably due to differences in feed and micronutrient intakes during the starter phase. Several micronutrients are known to influence carcass traits in broilers. Oduguwa *et al.* (2000) and Drażbo *et al.* (2018) reported beneficial effects of vitamins-minerals and amino acids intakes, respectively on carcass traits in broilers. Possible increase in the concentration of phenolic compounds in the ripe fruit as earlier mentioned may also be speculated. The depressed thigh muscle weight on the 0.25 % and subsequent improvement on the 0.5 % ripe powder was not understood. Contrary to these findings however, Sunder *et al.* (2007) reported improved dressing percentage in broilers fed 1.5 ml ripe noni fruit extract per bird per day compared to the control group. Increased intake of essential nutrients in noni fruit in the form of drink may be possible explanation of the improvement observed by these authors compared to intake from the feed in the present study, but more research is needed to establish this.

5 Conclusion

In conclusion, at 0.25 and 0.5 % inclusion, noni fruit powder has no beneficial effect on broiler growth, but the stage of noni fruit maturity may influence protein digestibility and dressing percentage. Nitrogen retention is reduced on 0.25 % green (unripe) noni powder and carcass and breast weights on 0.5 % ripe powder. A good understanding of the phytochemical properties of noni and effective dissemination of research findings may guide its efficient utilisation as additive in poultry diets. In addition, the suitability of noni plant in agroforestry systems will make it a valuable and cost effective additive, especially for small-scale rural producers, and promote the consumption of safer poultry products. The processing of noni fruit and composition of basal diet need more research for a better understanding of its effects on poultry performance.

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Conflict of interest

Authors state they have no conflict of interests.

References

AOAC (1995). *Official Methods of Analysis*. Association of Official Analytical Chemists, Arlington, USA.

Diarra, S. S., Amosa, F. & Lameta, S. (2019). Potential of Morinda (*Morinda citrifolia L.*) products as alternative to chemical additives in poultry diets. *Egyptian Journal of Veterinary Science*, 50 (1), 37–45.

Drażbo, A., Kozlowski, K., Chwastowska-Siwiecka, I., Sobczak, A. & Kwiatkowski, P. (2015). Effect of different dietary levels of DL-methionine and the calcium salt of DL-2-hydroxy-4-[methyl] butanoic acid on the growth performance, carcass yield and meat quality of broiler chickens. *Europ. Poult. Sci.*, 79, 1–14. doi 10.1399/eps.2015.114.

Eevuri, T.R. & Putturu, R. (2013). Use of certain herbal preparations in broiler feeds - A review. *Veterinary World*, 6, 172–179.

Flees, J., Rajaei-Sharifabadi, H., Greene, E., Beer, L., Hargis, B.M., Ellestad, L., Porter, T., Donoghue, A., Bottje, W.G. & Dridi, S. (2017). Effect of *Morinda citrifolia* (noni)-enriched diet on hepatic heat shock protein and lipid metabolism-related genes in heat stressed broiler chickens. *Frontiers in Physiology*, 8 (919). doi: 10.3389/fphys.2017.00919.

Hong, Y.H., Yi, Y.S., Han, S.Y., Aziz, N., Kim, H.G., Park S.H., Hossain, M.A., Baik, K.S., Choi S.Y., Lee J., Kim, J.H. & Cho J.Y. (2019). *Morinda citrifolia* noni water extract enhances innate and adaptive immune responses in healthy mice, ex-vivo, and in-vitro. *Phytotherapy Research*, 33 (3), 676–689.

Javed, M., Durrani, F.R. Hafeez, A., Khan, R.U. & Ahmad, I. (2009). Effect of aqueous extract of plant mixture on carcass quality of broiler chicks. *ARPN Journal of Agriculture and Biological Sciences*, 4, 37–40.

Jelveh, K., Rasouli, B., Seidavi, A. & Diarra, S.S. (2018). Comparative effects of Chinese green tea (*Camellia sinensis*) extract and powder as feed supplements for broiler chickens. *Journal of Applied Animal Research*, 46 (1), 1114–1117.

Millonig, G., Stadlmann, S. & Vogel, W. (2005). Herbal hepatoxicity: acute hepatitis caused by a noni preparation (*Morinda citrifolia*). *European Journal of Gastroenterology and Hepatology*, 17, 445–447.

Mirzaei, F. & Venkatesh, K.R.H. (2012). Efficacy of phyto medicines as supplement in feeding practices on ruminant's performance: A Review. *Global Journal of Research in Medicinal Plants and Indigenous Medicine*, 1, 391–403.

Mirzaei-Aghsaghali, A. (2012). Importance of Medical Herbs in Animal Feeding: A Review. *Annals of Biological Research*, 3, 918–923.

Mishra, A.K., Mishra, A., Bhargava, A. & Pandey, A.K. (2008). Antimicrobial activity of essential oils of leaves of *Cinnamomum spp.*. *National Academy Science Letters*, 31, 314–345.

Motshakeri, M. & Ghazali, H.M. (2015). Nutritional, phytochemical and commercial quality of noni fruit: a multibeneficial gift from nature. *Trends in Food Science and Technology*, 45, 118–129.

Narimani-Rad, M., Nobakht, A., Shahryar, H.A., Kamani, J. & Lotfi, A. (2011). Influence of dietary supplemented medicinal plants mixture (ziziphora, oregano and peppermint) on performance and carcass characterization of broiler chickens. *Journal of Medicinal Plant Research*, 5, 5626–5629.

Oduguwa, O.O., Oduguwa, B.O., Fanimo, A.O. & Dipeolu, M.A. (2000). Potency of two proprietary micronutrient premixes for broiler chickens at marginally deficient protein contents. *Archivos de Zootecnia*, 49, 433–444.

Santoso, U. & Fenita, Y.K. (2017). The effect of medicinal herb inclusion on the hematologic status and blood lipid profiles in broiler chickens. *International Journal of Poultry Science*, 16, 415–423.

Shalan, N.A.A.M., Mustapha, N.M. & Mohamed, S. (2016). Chronic toxicity evaluation of *Morinda citrifolia* fruit and leaf in mice. *Regulatory Toxicology and Pharmacology*, 83, 46–53.

Steel, R.G.D. & Torrie, J.H. (1980). *Principles and procedures of statistics: a biometrical approach* (2nd ed.). McGraw Hills Book Co., New York, USA.

Sunder, J., Rai, R.B., Yasmeen, J., Kundu, A. & Jeyakumar, S. (2007). Immunomodulatory effect of *Morinda citrifolia* in poultry. *Indian J. Anim. Sci.*, 77, 1126–1128.

Sunder, J., Kundu, A., Singh, D.R., Jeyakumar, S. & Srivastava, R.C. (2011). Effect of feeding *Morinda citrifolia* fruit juice on growth, production and immune response in Nicobari fowl. *Indian J. Anim. Sci.*, 81, 68–71.

Sunder, J., De, A.K., Jeyakumar, S. & Kundu, A. (2013a). Effect of feeding of *Morinda citrifolia* fruit juice on the biophysical parameters of healthy as well as mastitis-affected cow milk. *Journal of Applied Animal Research*, 41, 29–33.

Sunder, J., Jeyakumar, S., Sujatha, T. & Kundu, A. (2013b). Effect of feeding of morical: Herbal based supplement on production and egg quality in Japanese quails. *Advances in Animal and Veterinary Sciences*, 1, 157–160.

West, B.J., Jensen, C.J. J, Westendorf, J. & White, L.D. (2006). A safety review of noni fruit juice. *Journal of Food Science*, 71, 100—106.

Yamashita, Y., Katagiri, T., Pirarat, N., Futami, K., Endo, M. & Mata, M. (2009). The synthetic antioxidant, ethoxyquin, adversely affects immunity in tilapia (*Oreochromis niloticus*). *Aquaculture Nutrition*, 15, 144–151.

Yang, J., Gadi, R. & Thomson, T. (2011). Antioxidant capacity, total phenols, and ascorbic acid content of noni (*Morinda citrifolia*) fruits and leaves at various stages of maturity. *Micronesica*, 41 (2), 167–176.