Summary
VI. SUMMARY

A comprehensive study was conducted to evaluate the AZM as a feed ingredient at different levels in poultry diets. In addition to chemical evaluation of AZM, two metabolism trials (one each in broilers and layers) were performed to arrive at the metabolizable energy of AZM and using such values, two performance trials of independent nature, one in broilers to assess the growth performance and carcass characteristics of young growing birds and another in layers to assess the production performance and egg characteristics of peak laying hens, both fed diets containing AZM at different levels. The results of the experiments conducted are summarized as below:

A. Chemical composition

The fresh Azolla harvested contained 4.44 per cent DM. On an average, sun-dried AZM sample contained 91.75 per cent DM, 70.83 – 81.25 per cent organic matter (OM) and 18.75–29.17 per cent total ash (TA). The crude protein (CP), crude fibre (CF), ether extract (EE) and nitrogen free extractives (NFE) contents of sun-dried AZM ranged from 24.12 – 25.82, 16.25 – 19.85, 3.80 – 4.85 and 26.66 – 33.05 per cent respectively. The corresponding proximate constituents of sun-dried Azolla microphylla sample procured from G.K.V.K contained dry matter – 91.98, organic matter – 75.83, total ash – 24.17, crude protein – 24.56, crude fibre – 15.17, ether extract – 3.38 and NFE – 32.72 per cent with acid insoluble ash of 7.19 per cent.
B. Metabolism trial in broilers

1. The chemical analysis of AZM revealed that it is a good valuable source of organic nutrients and its nutrient composition was comparable to that of cereal by-products.

2. A total of eight diets were prepared by part-by-part replacing basal mixture (T\textsubscript{1}) with sun dried AZM at 10 (T\textsubscript{3}), 20 (T\textsubscript{5}) and 30 per cent (T\textsubscript{7}) and each such diets were further supplemented with fibre degrading enzyme (T\textsubscript{2}, T\textsubscript{4}, T\textsubscript{6} and T\textsubscript{8}). Each diet was offered to duplicate groups of 10 chicks each for a period of 14 days which included terminal 3 days of collection period.

3. The per cent metabolizability coefficient of DM, OM, CP, EE, GE and ME content of experimental diets were highly significant (P<0.01) and the values ranged from 61.31 (T\textsubscript{7}) to 72.58 (T\textsubscript{1}), 69.80 (T\textsubscript{7}) to 77.36 (T\textsubscript{1}), 46.95 (T\textsubscript{7}) to 76.61 (T\textsubscript{1}), 57.05 (T\textsubscript{7}) to 67.26 (T\textsubscript{1}), 69.26 (T\textsubscript{7}) to 76.74 (T\textsubscript{1}) and from 2644 (T\textsubscript{7}) to 3068 per cent (T\textsubscript{1}), respectively. The average ileal N absorbability values under different treatments also significantly (P<0.05) varied from 65.80 (T\textsubscript{4}) to 81.99 per cent (T\textsubscript{3}). As a general trend, the metabolizability coefficients of different components of experimental diets tended to decrease with the incremental level of AZM (0, 10, 20 and 30%). But the metabolizability coefficient was not affected by the fibre degrading enzyme.

4. The metabolizability coefficient of EE, GE and ME of AZM (test ingredient) under different treatments were highly significant (P<0.01) and the values were ranged from 17.86 to 66.78, 51.28 to 70.08 and 1549 to 2026 per cent, respectively. The metabolizability coefficient values for DM was significantly lower (P<0.05) with the values ranging from 29.11 to 39.01 per cent. The metabolizability coefficient of OM, CP and the absorbability of nitrogen content of AZM in the ileum was found to be
statistically similar (P>0.05) among different treatments with the values ranging from 46.60 to 61.06, 31.17 to 33.80 and 71.90 to 104.20 per cent, respectively.

5. On an average the metabolizability of different components of AZM was as follows: DM: 34.23, OM: 52.42, crude protein: 30.84, EE: 35.56, GE: 57.40 per cent and ME: 1725 kcal. The absorbability of its nitrogen in the ileum was about 71.61 per cent.

C. Metabolism trial in layers

6. A total of eight diets were prepared by replacing part-by-part of basal mixture (T₁) with sun dried AZM at 10 (T₃), 20 (T₅) and 30% (T₇) and each of such diets was further supplemented with fibre degrading enzyme (T₂, T₄, T₆ and T₈). Each diet was offered to four groups of 4 laying hens (35 week old) each for a period of 14 days which included terminal 3 days of collection period.

7. The metabolizability coefficient of proximate principles of experimental diets namely DM, OM, CP, EE, CF and NFE content ranged from 57.52 (T₈) to 68.14 (T₁), 62.42 (T₇) to 73.72 (T₁), 53.80 (T₇) to 60.26 (T₁), 66.18 (T₈) to 75.44 (T₂), 25.44 (T₈) to 31.97 (T₁) and from 72.07 (T₈) to 82.81 (T₁) per cent, respectively. The percent metabolizability coefficient of GE content of different experimental diets were ranged from as low as 66.43 (T₈) to as high as 74.71 (T₁). The variation among different treatments were found to be highly significant (p<0.01) for all the proximate principles, GE and ME and except for the CP and CF. In general, there was a decreased metabolizability coefficient of different components of experimental diets with the incremental level of AZM.
8. The mean ME values derived for the sample of AZM at 10, 20 and 30 per cent inclusion levels varied from 691 to 1549 kcal/kg, with an average of 1152 kcal/kg. The metabolizability coefficient of DM of AZM under different treatments was significant (p<0.05) and the values ranged from 11.40 to 33.08 per cent. Irrespective of its level of inclusion and supplementation of enzyme, on an average the metabolizability of different components of AZM is as follows: DM: 28.45, OM: 33.00, crude protein: 49.58, EE: 50.15, crude fibre: 16.25, and NFE: 44.60 per cent. With regard to the main factor enzyme supplementation, the metabolizability of all proximate principles of AZM were found to be statistically similar (P>0.05) among the different treatments.

D. Growth performance trial in broilers

9. By making use of the ME value obtained during the metabolic trial in broilers, five iso-nitrogenous and iso-caloric experimental diets were formulated by incorporating sun dried AZM at 2.5, 5, 7.5 and 10 per cent. The diets containing 0 (control; T2), 2.5 (T4), 5 (T6), 7.5 (T8) and 10 per cent AZM (T10) were further supplemented with fibre degrading enzyme to result in another 5 diets. Each such diet was prepared for starter (0-14 days), grower (15-28 days) and finisher (29-42 days) phases and offered to duplicate groups of 10 chicks each.

10. The cumulative average body weight gains among different treatments were statistically similar (P>0.05) with the values ranging from 1949 (T3) to 2109 g/bird (T5). For main factor AZM, The cumulative values were found to be 2082, 2013, 2070, 1998 and 2015 g/bird for 0, 2.5, 5, 7.5 and 10 per cent AZM included diets, respectively and for the enzyme supplementation, the cumulative values were found
to be higher in non supplemented diets of fibre degrading enzymes (2040 g) and lowest in supplemented diets (2031 g) which varied non-significantly.

11. The per cent livability of birds under different treatments were statistically (P>0.05) similar. The livability was 100 per cent in all groups.

12. Cumulative average feed consumption ranged non-significantly (P≥0.05) from 4030 g/bird (T₁) to 4287 g/bird (T₀) during 42-day experimental period. AZM and enzyme supplementation as main factors showed non-significant (P>0.05) differences in cumulative feed consumption.

13. The cumulative average FCR (kg feed/kg weight gain) was found to be significantly (P≤0.01) better in T₂ (1.923) and poorer in T₁₀ (2.126). With respect to the main factor AZM, the cumulative average FCR values were 1.936, 2.040, 2.005, 2.053 and 2.103 for 0, 2.5, 5, 7.5 and 10 per cent AZM based diets, respectively i.e., the poorest FCR in 10 per cent AZM. Further, it was also evident that the diets incorporated with AZM showed numerically inferior FCR compared to control during all the weeks, phases and cumulatively. For the main factor of enzyme supplementation, the cumulative FCR values were 2.035 (non supplement) and 2.020 (fibre degrading enzyme) which were statistically (P>0.05) similar when compared to one another.

14. The dressing percentage values was non-significantly (P>0.05) highest in T₁ (79.71) and lowest in T₀ (77.89). As regard to the main factors AZM and enzyme supplementation, the dressing percentage values were also statistically similar. Similar results were observed regarding meat to bone ratio and drum stick yield. Likewise, abdominal fat content 18.95 (T₂) to 38.08 g/bird (T₃) or 1.27 (T₂) to 2.67 % (T₃) of per cent live body weight, The breast meat yield values expressed as per
cent of dressed body weight 15.07 ($T_3$) to 19.36 per cent ($T_6$) and the relative percent weights of giblet organs viz., liver, heart and gizzard remained statistically ($P>0.05$) similar among all groups. The relative values were also non-significantly different for both the main factors, AZM and enzyme supplementation. Similar trend was observed in the case of proventriculus also.

15. In case of lymphoid organs viz., spleen, the relative weights under different treatment groups were statistically ($P>0.05$) similar with values ranging from 0.09 ($T_5$) to 0.19 per cent ($T_1$). But the relative weights of bursa among different treatments were highly significant ($p<0.01$) and the weights ranged from 0.10 ($T_4$) to 0.34 per cent ($T_{10}$). The values with regard to main factor AZM were non-significant ($P>0.05$) for spleen but significant ($P<0.05$) for bursa. The main factor enzyme supplementation showed non-significant relative weights of spleen and bursa.

16. The relative length of different segment of small intestine viz., duodenum, jejunum and ileum of birds under different dietary treatment groups were found to be statistically ($P>0.05$) similar. The relative length of intestinal segments were also differed non-significantly for the main factors, AZM. But for the main factor of enzyme supplementation, the relative length of duodenum were statistically significant ($P<0.05$) but not for the jejunum and ileum.

17. In all the cases (starter, grower and finisher diets), the cost of AZM incorporated diets were higher than that of the corresponding control diets. The net profit per bird among different treatment groups ranged highly significantly ($p<0.01$) from Rs 3.55 in ($T_{10}$) to Rs.12.40 in ($T_2$). With regard to AZM as the main factor, the relative net profit values per bird under different treatments differed significantly ($P<0.05$) but
for the enzyme supplementation as the main factor, the relative net profit values per bird differed non-significantly (P>0.05). The Performance Index values were found to be statistically significant (P<0.05) among different treatments and the values ranged from 225 (T\textsubscript{10}) to 265 (T\textsubscript{2}). With regard to AZM as the main factor, the relative PIS differed significantly (P<0.05) but the enzyme supplementation as the main factor, the relative PIS values varied non-significantly (P>0.05). With respect to the Economic Index Score, the values were highly significant (p<0.01) among different treatments and ranged between 18.00 in (T\textsubscript{10}) and 22.26 in (T\textsubscript{2}). With regard to main factors, the AZM also showed highly significant (p<0.01) differences in the relative EIS values, while enzyme supplementation remained statistically similar (P>0.05).

**E. Egg production performance trial in layers**

18. Using the ME value of AZM obtained from metabolism trial in layers, five iso-nitrogenous and iso-caloric experimental diets were formulated by incorporating sun dried AZM at 2.5, 5, 7.5 and 10 per cent. The diets containing 0 (control; T\textsubscript{2}), 2.5 (T\textsubscript{4}), 5 (T\textsubscript{6}), 7.5 (T\textsubscript{8}) and 10 per cent AZM (T\textsubscript{10}) were further supplemented with fibre degrading enzyme to result in another 5 diets. Each such diet was offered to four groups of 4 laying hens each. The feeding trial was carried out for 84 days, which was divided into three periods of 28-day interval each.

19. The cumulative average egg production ranged highly significantly (p<0.01) from 81.77 (T\textsubscript{8}) to 89.21 (T\textsubscript{2}) per cent among different treatments. The cumulative values were 86.27, 87.91, 87.91, 82.48 and 84.93 per cent for 0, 2.5, 5, 7.5 and 10 per cent
AZM based diets, respectively. As regards to the enzyme supplementation, the cumulative egg production values were found to be statistically similar.

20. Cumulatively the average feed consumption values were highly significant (p<0.01) among different treatments and ranged from 117.4 (T_2) to 118.7 g/hen/day (T_9). The cumulative feed efficiency (FE) among different treatment groups was found to be highly significant (p<0.01) and was found to be better in T_2 (1.447) while it was poorer in T_8 (1.717 kg feed / dozen eggs) group and the values ranged between 2.272 (T_3) and 2.463 (T_8) respectively. With regard to the main factors, the cumulative average FE values as affected by AZM factor were highly significant (p<0.01) in that both 7.5 and 10 per cent AZM included groups (1.679 and 1.603 kg feed/dozen eggs, respectively) were significantly (p<0.01) poorer than that observed with control (1.571 kg feed/dozen eggs) group. As regards the enzyme supplementation, highly significant (p<0.01) differences were observed in FE. The cumulative pooled over values were 1.579 and 1.561 kg feed/dozen eggs in non supplement and fibre degrading enzyme supplemented groups. Such trend was not noticed when FE was expressed as kg feed / kg egg mass for enzyme supplementation cumulatively.

21. The mean cumulative body weight changes showed a gain in body weights and that such positive values ranged from as low as 63.00 (T_1) to as high as 107.56 g (T_5). The body weight changes on cumulative basis were found to be highly significant (P<0.01) when the data was analyzed as per the AZM level. Enzyme supplementation did not affect the body weight changes.

22. The cumulative egg weight differed significantly (p<0.01) among different treatments with the values ranging from 57.17 (T_2) to 60.18 g (T_7). As far as the
main factors were concerned, AZM inclusion showed highly significant (p<0.01) values on cumulative basis. The cumulative average egg weight values were 58.80 and 59.40 g in diets supplemented with fibre degrading enzyme and non-supplemented which were statistically similar. The average Egg Shape Index (ESI) values ranged non-significantly (P>0.05) from 72.54 (T2) to 77.11 (T10) on 84th day. With regards to the main factor, AZM levels showed highly significant (p<0.01) variation among different groups cumulatively and the values ranged from 74.37, 75.79, 75.67, 74.48 and 76.87 for 0, 2.5, 5, 7.5 and 10 per cent AZM incorporated diets on cumulative basis. With regard to the main factor of enzyme supplementation, it showed significant (P<0.05) variation among different groups cumulatively where the fibre degrading enzyme supplemented diets produced better egg shape index (75.90) than non-supplemented one (74.98).

23. The mean albumen index values pooled over the periods (cumulative) ranged from 5.62 (T10) to 6.84 (T5), which were highly significant (P<0.01) from each other. As regards the main factor of AZM, the albumen index scores were found to be non-significant (P>0.05) cumulatively. But for the main factors of enzyme supplementation, the albumen index scores were found to be highly significant (P<0.01). The pooled over (periods) mean values of Haugh unit scores ranged significantly (p<0.01) from 66.20 (T10) to 74.18 (T5). As regards the main factors of AZM level, the HUS were found to be statistically significant (P<0.05) on cumulative basis. As regards the main factors of enzyme supplementation, the HUS were found to be highly significant (p<0.01) on cumulative basis and the values ranged from 68.64 for enzyme supplemented and 72.00 for non-supplemented.
24. The influence of different treatment diets in imparting colour to the yolks was found to be highly significant (P<0.01) at 28th day, 56th day and 84th day of the experiment and as well as cumulatively. As regards main factors, the yolk colour scores were significantly (p<0.01) affected by the AZM factor on the 28th, 56th and 84th day and cumulatively, with the values ranging from 5.09 (control) to 7.50 (7.5% AZM) during period-I, from 4.79 (control) to 8.11 (7.5 and 10 % AZM) during period-II, from 4.79 (control) to 8.11 (10% AZM) during period-III and from 4.83 (control) to 8.09 (10% AZM) cumulatively. As regards main factors, the yolk colour scores were significantly (p<0.01) affected by the enzyme supplementation factor on the 56th, 84th day and cumulatively. The treatment wise average yolk index values ranged from 37.38 (T10) to 39.27 (T1) on cumulative basis which differed highly significantly (P<0.01). As regards main factors of AZM, the average yolk index values were significantly (p<0.01) affected by the AZM factor on cumulative basis. As regards the main factors of enzyme supplementation, the yolk index values were significantly (P<0.05) affected by the enzyme supplementation on cumulative basis.

25. The treatment wise egg shell thickness values among different groups ranged from 0.336 (T3) to 0.356 mm (T9) with statistically significant (P<0.05) differences. Among the main factor effects of AZM, the cumulative average egg shell thickness values were 0.340, 0.337, 0.348, 0.352 and 0.349 mm at 0, 2.5, 5, 7.5 and 10 per cent levels of inclusion of AZM which differed highly significantly (p<0.01) among themselves. For the main factor of enzyme supplementation, the egg shell thickness values were statistically (P>0.05) similar throughout the experiment.
26. The treatment wise results revealed that the per cent efficiency of protein utilization values were significant (P<0.05) cumulatively in that it ranged from as low as 27.68 (0 % AZM included diet) and as high as 29.95 (T₃-2.5 % AZM). Similarly the efficiency of energy utilization was found to be as high as 28.76 (T₃) to as low as 26.64 (T₁) which differed statistically (P<0.05). The main factor effects of AZM, on EEU were found to be significant (P<0.05) on cumulative basis. Enzyme supplementation had no affect on protein or energy utilization.

27. The mean net returns ranged highly significantly (P<0.01) from 8.42 (T₈) to 14.97 (T₃), cumulatively. The effect of main factors of AZM revealed that the net returns were highly significantly (P<0.01) affected by the main factor. Cumulatively the incremental levels of AZM gradually reduced the net returns from Rs. 14.30 to 8.06 in 2.5 to 7.5 per cent AZM diets, respectively. Enzyme supplementation has no affect on net returns.
CONCLUSION

The chemical analysis indicated that the sun-dried azolla meal (AZM) is a good source of protein and energy. The biological experiments revealed that the nutritive value of AZM is moderate. The metabolizable energy content of AZM is around 1525 kcal/kg. The growth performance of broilers was affected by inclusion of AZM as a feed ingredient at 2.5, 5, 7.5 and 10 per cent in the diets (iso-nitrogenous and iso-caloric diets). Similarly, the egg production parameters in layers also affected at these levels. However, the carcass characteristics of broilers were not affected except for the breast meat yield while the egg quality parameters of layers were affected by AZM inclusion. The supplementation of fibre degrading enzyme to improve the nutritive value of AZM was found to be ineffective.

By considering the parameters of economic importance i.e., feed consumption, body weight gain and feed efficiency in broilers and feed consumption, nutrient utilization, egg production and feed efficiency in layers, it was concluded that the inclusion of AZM at 5 per cent level in both broiler and layer diets is beneficial. But AZM can be included up to 10 per cent without any side effects. It also concluded that the enzyme supplementation was not beneficial in improving the utilization of AZM at any level.

Thus, the scope for inclusion of AZM as an unconventional feed source in diets of non-ruminants particularly in poultry diets beyond 10 per cent level is not feasible.