Neem (Azadirachta indica) Seed Cake in Animal Feeding—Scope and Limitations
- Review -

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ABSTRACT: The different products of neem (Azadirachta indica) are utilized for variety of purposes in industry, health and animal agriculture in the Indian subcontinent. The cake from seeds after oil extraction is a good source of nutrients (CP: 35-38%; EE: 4.5-5.5%; CF: 12-15%; Ca: 0.75%; P: 0.45% on DM), and in particular, the one out of its kernel is proteinaceous and is relatively balanced in its amino acid and mineral profile. But the cake is toxic and bitter to taste owing to triterpenoids (nimbin, salamin, azadirachtin), which restricts its safe inclusion in livestock diet. Several feeding trials with raw cake have revealed poor palatability and adverse performance among different categories of livestock and poultry. Internal organ changes included histological alteration in intestine, liver, kidney and disruption of spermatogenesis and ovarian activity. Ruminants appears to tolerate reasonably higher levels of the cake and to a limited low levels of dietary inclusion also proved to be tolerable in monogastric farm animals. Debitterization through solvent (hexane, ether) extraction, water washing, alkali (NaOH, 1.5, 2.5 or 3%, wt/vol) soaking and urea (1.5 or 3%, wt/vol) - ammoniation have been tried with appreciable success in improving the palatability and nutritive value of the cake. For enhanced utilization, decortication of neem seeds is to be done effectively at industrial level with maximum oil recovery. The resultant proteinaceous kernel by-product could be a cheaper unconventional protein supplement after suitable processing. (Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 5 : 720-728)

Key Words: Neem Seed Cake, Animal Feeding, Toxic Effects, Unconventional Feed

INTRODUCTION

Neem (Azadirachta indica, Azadirachta juss), a member of family melicaceae is a large, evergreen and fast growing tree native to Indian subcontinent and viewed with great esteem. It is an indispensable component of Indian ecosystem widely spread even to Pakistan, Bangladesh, Sri Lanka, Malaysia, Indonesia, Thailand, Middle East, Africa and also to Australia (Randhawa and Parmar, 1993). Neem is universally accepted as a wanted tree exhibiting high degree of heterogeneity and can tolerate a long dry season with rain fall as low as 130 mm. It thrives successfully on dry, clay and shallow soils with pH ranging from 5 to 8.5 (Anonymous, 1985). Derivatives of neem are used in agriculture, medicine, cosmetics and in livestock production and health. According to a rough estimate, India harbours about 25 million neem trees with an average annual production potential of 0.9 million tonnes of neem seed cake (NSC) (Singh, 1993). Products of neem includes neem oil (NO), neem bark, leaves and seeds. The collected seeds are subjected to oil extraction and the resultant left back residue is termed as NSC. Single seeded mature neem fruit contains 23.8% skin, 47.5% pulp, 18.6% shell and 10.1% kernel (Ketkar, 1976). The decortication of depupled seed yields about 26% kernel, which gives 45 to 50% oil leaving the rest as neem kernel cake (NKC).

Bitter principles of neem

Neem contains a vast variety of biologically active compounds which are chemically diverse and structurally complex. Such constituents of neem have been divided into two major fractions viz., Isoprenoids and others, of which former is subdivided into Diterpenoids and Triterpenoids. The bitterness of neem is attributed to limonoids, which are the triterpenoids based on apo-euphol skeleton structure (Lavie and Levy, 1971). Bitter principles of neem can be conveniently categorised into eight groups: protomeliciains, limonoids with a modified side chain, azadirone and its derivatives, gedunin and its derivatives, viasin type compounds and those belonging to three C- Secomeliciains viz., nimbin, salamin and azadirachtin. The chemistry and structure of the above constituents with their analogues has been extensively reviewed by Devakumar and Sukhdev (1993). Most limonoids are present in trace amounts of less than 0.001 to 0.1%. Higher quantities are identified for azadirone (0.45%) and epoxy azadirone (0.72%) in dried seeds (Kraus et al., 1981), azadiradione (0.7%) in dried fruits (Kraus and Cranner, 1978) and salamin (0.95%) in seed oil (Henderson et al., 1968). The nonisoprenoid polyphenolics of neem includes flavonoids (Basak and Chakraborty, 1968), tannins (Hegauwer, 1983) and coumarin (Siddiqui et

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Table 1. Chemical composition of various types of neem cake (%DM)

<table>
<thead>
<tr>
<th>Cake/meal</th>
<th>CP</th>
<th>EE</th>
<th>CF</th>
<th>NFE</th>
<th>Ash</th>
<th>Ca</th>
<th>P</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSC</td>
<td>12.35</td>
<td>3.3</td>
<td>17.9</td>
<td>52.52</td>
<td>13.93</td>
<td>-</td>
<td>-</td>
<td>Bedi et al. (1975a)</td>
</tr>
<tr>
<td>NSC</td>
<td>17.85</td>
<td>3.62</td>
<td>25.90</td>
<td>46.20</td>
<td>5.5</td>
<td>0.72</td>
<td>0.58</td>
<td>Christopher (1976)</td>
</tr>
<tr>
<td>NSC (Exp.)</td>
<td>19.40</td>
<td>8.60</td>
<td>25.84</td>
<td>37.86</td>
<td>8.84</td>
<td>0.41</td>
<td>0.61</td>
<td>Pyne et al. (1979)</td>
</tr>
<tr>
<td>Neem fruit cake</td>
<td>14.97</td>
<td>2.40</td>
<td>26.95</td>
<td>40.92</td>
<td>15.17</td>
<td>1.65</td>
<td>0.31</td>
<td>Rao &amp; Nath (1979)</td>
</tr>
<tr>
<td>NKC</td>
<td>33.50</td>
<td>10.40</td>
<td>11.40</td>
<td>29.70</td>
<td>15.00</td>
<td>-</td>
<td>-</td>
<td>Nath et al. (1983)</td>
</tr>
<tr>
<td>WNWKC</td>
<td>34.70</td>
<td>9.20</td>
<td>12.40</td>
<td>28.90</td>
<td>14.80</td>
<td>-</td>
<td>-</td>
<td>Nath et al. (1982)</td>
</tr>
<tr>
<td>NSM</td>
<td>35.51</td>
<td>9.14</td>
<td>11.89</td>
<td>28.48</td>
<td>14.98</td>
<td>0.77</td>
<td>0.69</td>
<td>Chand (1987)</td>
</tr>
<tr>
<td>Hexane Ex. NSM</td>
<td>38.31</td>
<td>1.06</td>
<td>13.46</td>
<td>29.02</td>
<td>18.15</td>
<td>1.05</td>
<td>1.08</td>
<td>Chand (1987)</td>
</tr>
<tr>
<td>Alcohol Ex. NSM</td>
<td>40.35</td>
<td>0.71</td>
<td>13.92</td>
<td>26.02</td>
<td>19.00</td>
<td>1.12</td>
<td>1.11</td>
<td>Chand (1987)</td>
</tr>
<tr>
<td>NSC</td>
<td>20.90</td>
<td>14.80</td>
<td>19.20</td>
<td>29.50</td>
<td>15.50</td>
<td>0.14</td>
<td>0.81</td>
<td>Reddy et al. (1988b)</td>
</tr>
<tr>
<td>FFNSM</td>
<td>16.80</td>
<td>22.80</td>
<td>34.61</td>
<td>23.10</td>
<td>2.7</td>
<td>-</td>
<td>-</td>
<td>Fuzinmi et al. (1989)</td>
</tr>
<tr>
<td>FFNSM</td>
<td>14.20</td>
<td>27.00</td>
<td>40.50</td>
<td>14.00</td>
<td>4.3</td>
<td>0.07</td>
<td>0.01</td>
<td>Salawu et al. (1994)</td>
</tr>
<tr>
<td>DNSC</td>
<td>18.37</td>
<td>0.38</td>
<td>30.12</td>
<td>34.97</td>
<td>16.16</td>
<td>0.97</td>
<td>0.16</td>
<td>Garg (1989)</td>
</tr>
<tr>
<td>ATNKC</td>
<td>33.76</td>
<td>5.39</td>
<td>13.77</td>
<td>27.28</td>
<td>19.90</td>
<td>-</td>
<td>-</td>
<td>Katiyar et al. (1993)</td>
</tr>
<tr>
<td>UANKC</td>
<td>40.91</td>
<td>4.44</td>
<td>11.43</td>
<td>28.10</td>
<td>15.12</td>
<td>-</td>
<td>-</td>
<td>Katiyar et al. (1991)</td>
</tr>
<tr>
<td>ATNKM</td>
<td>36.01</td>
<td>4.80</td>
<td>15.60</td>
<td>27.80</td>
<td>15.80</td>
<td>0.78</td>
<td>0.50</td>
<td>Gowda et al. (1998a)</td>
</tr>
<tr>
<td>UANKM</td>
<td>40.06</td>
<td>4.90</td>
<td>15.30</td>
<td>24.12</td>
<td>15.62</td>
<td>0.74</td>
<td>0.45</td>
<td>Gowda et al. (1998a)</td>
</tr>
</tbody>
</table>

NSC: Neem seed cake; NKC/NKM: Neem kernel cake/meal; WNWKC: Water washed NKC; NSM: Neem seed meal; FFNSM: Full fat NSM; DNSC: Decoiled NSC; ATNKC/ATNKM: Alkali treated NKC/NKM; UANKC/UANKM: Urea-ammoniated NKC/NKM.

al., 1986).

Common uses of neem products

Neem seed cake as such was found unsuitable as a wholesome animal feed due to the bitterness and hence widely utilized as a fertilizer (Chandra and Shrikhande, 1955) and insect repellent and insecticide (Mitra, 1963). The cake contains 5.2% N, 1.1% P2O5 and 1.5% K2O (Khan, 1952) and serves as a good manure. In addition, the nitrification inhibiting property of NSC is in routine use by coating urea granules for slow release of ammonia in the soil (Reddy and Prasad, 1975; Sahrawat, 1982). Neem extracts are known to exhibit anti-diabetic, anti-bacterial and anti-viral properties and also used against gut worms and ulcers in humans (Singh, 1993). Neem products are also known to possess spemcical properties (Riar, 1993).

Neem cake as an animal feed

The possibility of using NSC in livestock ration was explored by Christopher (1970) basing on the feeding practice of local farmers in South India. Though bitter to taste in the beginning, animals fast get used to it and were in good health (Ketkar, 1976). Following such observations, several researchers evaluated this agro-industrial by-product for chemical composition and nutritive value through animal feeding.

Chemical composition

The chemical composition of neem cake varies considerably (table 1) depending upon type of processing, such as solvent or expeller extraction of undecorticated or decorticated seeds. The cake from the kernel of whole seeds is highly proteinaceous and low in fibre. The crude protein (CP) content varied from 12.35 in NSC to 40.35% in alcohol extracted NKC with still higher values after urea-ammoniation. The ether extract (EE) varied from 0.2 to 27% with higher values (8.6-27%) in expeller extracted and full fat neem seed meal (FFNSM) and lower (0.2-2.4%) in solvent extracted cake. The crude fibre (CF) ranged from 11.43% in urea-ammoniated NKC (UANKC) to 30.51% in decoiled neem fruit cake and 40.5% in FFNSM, which was inversely related to CP content. The cake produced from whole neem fruit (including pulp) would be low in CP and high in CF. Partially depulped and undecorticated or completely depulped and undecorticated or partially decorticated neem seeds would give an intermediate value of CP and CF, depending on the extent of depulping and decortication.

Mineral composition (table 2) and amino acid profile (table 3) of neem cake compares well with the other cakes. It is balanced in Ca, P but exceptionally high in K and Fe. Neem cake consists of all essential and non-essential amino acids including sulphur containing ones but with less amounts of histidine, lysine and tyrosine.

Nutritive value

The undecorticated NSC contained 6.5, 8.8 and 11.6% DCP for cattle (Ananthasubramaniam et al.,
Table 2. Mineral profile of certain neem products (DM basis)

<table>
<thead>
<tr>
<th>Product</th>
<th>%</th>
<th>ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ca</td>
<td>P</td>
</tr>
<tr>
<td>Neem leaves*</td>
<td>0.72</td>
<td>0.27</td>
</tr>
<tr>
<td>Neem fruit*</td>
<td>0.29</td>
<td>0.36</td>
</tr>
<tr>
<td>Neem seed*</td>
<td>0.77</td>
<td>0.31</td>
</tr>
<tr>
<td>Neem cake*</td>
<td>0.96</td>
<td>0.30</td>
</tr>
<tr>
<td>FFNSM**</td>
<td>0.07</td>
<td>0.01</td>
</tr>
</tbody>
</table>

* Singhal and Mudgal (1984); ** Salawu et al. (1994).

Table 3. Relative amino acid composition of neem seed cake and peanut meal

<table>
<thead>
<tr>
<th>Amino acid (%DM)</th>
<th>NSC*</th>
<th>NSC**</th>
<th>PNM***</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspartic acid</td>
<td>1.31</td>
<td>1.17</td>
<td>-</td>
</tr>
<tr>
<td>Threonine</td>
<td>0.50</td>
<td>0.30</td>
<td>1.40</td>
</tr>
<tr>
<td>Serine</td>
<td>0.58</td>
<td>0.46</td>
<td>-</td>
</tr>
<tr>
<td>Glutamic acid</td>
<td>2.40</td>
<td>2.42</td>
<td>-</td>
</tr>
<tr>
<td>Proline</td>
<td>0.84</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Glycine</td>
<td>1.08</td>
<td>0.39</td>
<td>2.21</td>
</tr>
<tr>
<td>Alanine</td>
<td>-</td>
<td>0.46</td>
<td>-</td>
</tr>
<tr>
<td>Cystine</td>
<td>1.73</td>
<td>0.34</td>
<td>0.61</td>
</tr>
<tr>
<td>Valine</td>
<td>0.76</td>
<td>0.48</td>
<td>2.20</td>
</tr>
<tr>
<td>Methionine</td>
<td>0.70</td>
<td>0.14</td>
<td>0.60</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>0.60</td>
<td>0.33</td>
<td>2.00</td>
</tr>
<tr>
<td>Leucine</td>
<td>0.95</td>
<td>0.71</td>
<td>3.10</td>
</tr>
<tr>
<td>Tyrosine</td>
<td>0.26</td>
<td>0.26</td>
<td>1.71</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>0.80</td>
<td>0.62</td>
<td>2.30</td>
</tr>
<tr>
<td>Histidine</td>
<td>0.21</td>
<td>0.16</td>
<td>1.00</td>
</tr>
<tr>
<td>Lysine</td>
<td>0.28</td>
<td>0.28</td>
<td>1.30</td>
</tr>
<tr>
<td>Arginine</td>
<td>0.57</td>
<td>0.73</td>
<td>4.69</td>
</tr>
</tbody>
</table>

* Singhal and Mudgal (1986).
*** Church and Pond (1982).

NSC: Neem seed cake; PNM: Peanut meal.

1979), buffalo bulls (Bedi et al., 1975b) and sheep (Gupta and Bhaiid, 1980), respectively with corresponding TDN values of 62.6, 57.87 and 37.9% (incomplete cake consumption). However, higher DCP values of 27.37% was reported by Rajgopal and Nath (1981) in NKC having 38.84% CP. Reddy et al. (1988b) arrived at higher true meabolizable energy (kcal/kg) for decorticated (2959) than for undecorticated (2.790) cake in broiler chicks. Gowda et al. (1997) reported apparent ME value of 1.925 kcal for neem kernel meal in poultry. The gross protein value of variously processed neem seed meal (NSM) ranged from 55 to 59%, as compared to 64% for peanut meal (PNM).

Palatability

The NSC was found unpalatable to buffalo calves (Bedi et al., 1975b), cattle calves (Rao and Nath, 1979), crossbred balls (Ananthasubramaniam et al., 1979) and sheep (Gupta and Bhaiid, 1980). Palatability though improved when NSC was fed to sheep along with barley, molasses and PNM, the consumption of concentrate mixture was reduced from 79 to 39% with increase in NCS level from 59 to 90%, respectively (Bhandari and Joshi, 1974). On the otherhand, yearling sheep could completely consume concentrate mixture comprising 75 parts NSC and 25 parts maize (Gupta and Bhaiid, 1980), but the consumption was reduced to one third when NSC was fed alone. The buffalo calves though continued to relish even after enhancing NSC from 5 to 15 parts when fed along with 7 and 20 parts of molasses and PNM respectively, the consumption was reduced to half on withdrawl of molasses (Baxi, 1976).

By feeding different proportions of NSC to buffalo calves along with molasses (4:1, 2:1), starch (4:1, 2:1) or maize (8:1, 4:1 and 2:1), it was observed that 67% NSC with 33% maize was quite palatable (Arora et al., 1975). Depression of 60% feed intake could be corrected by curtailling NSC to provide DCP requirement from 25 to 12.5% in the ration of buffalo calves (Bedi et al., 1975b). However, inclusion of deoiled NSC (DNSC : Garg, 1989) and NKC (Rao and Nath, 1981) upto 45% of the concentrate mixture resulted in higher DM intake in cow and bull calves, respectively. The feed consumption of broiler chicks was depressed on feeding deoiled neen seed meal (DNSM) at 5, 10, 15 and 30% (Subbacayudu and Reddy, 1975) and raw NSM (RNSM) at 30% (Choudhary et al., 1981) of dietary level. Similar depression in feed intake was recorded in rats fed 14% neem kernel meal (NKM) containing diet (Garg et al., 1984). Reduced feed intake was also noticed in broiler chicks and rabbits fed graded levels of FFNSM initially, and tolerance to the bitterness was noticed during the finishing phase (Salawu et al., 1994). Vasanthkumar et al. (1995) also recorded similar reduction in feed intake in rabbits due to inclusion of 20% NKM. However, incorporation of processed (alkali and urea) NKM in composite diet of rabbits
resulted in higher feed consumption in order to compensate for low energy density of NKM ( Gowda et al., 1998a).

**Debitterization**

Attempts were also made to debitterize the cake for improved palatability through solvent extraction (Nath et al., 1974; Sadagopan et al., 1981; Vijjan, 1983), alcohol treatment (Gupta et al., 1975), alkali (0.8% NaOH, wt/wt) boiling (1:2.5 wt/vol) of cake followed by water washing (Nath et al., 1978; Rao and Nath, 1979), and overnight water soaking with repeated washing (Nath et al., 1983; Agrawal et al., 1987). However, either water washing alone or alkali treatment followed by water washing was found successful in improving the palatability due to the removal of neem butters but also resulted in 22 to 40% DM loss due to washing. In order to overcome DM loss comprising mostly of soluble sugars and amino acids, simple overnight soaking of cake in alkali (NaOH, 3%, wt/wt) solution (1:1.5 wt/vol) without water washing proved palatable to adult cattle and buffaloes (Katiyar et al., 1993), due to debitterising effect of alkali and urea in alkaline medium. To economise the alkali processing of NKC, fertilizer grade urea (3.5%, wt/wt) was employed for ammoniation in semisolid (1:1.4, wt/vol) medium through ensiling for 5 days in an air tight silo and the sundried and ground ammoniated cake was well relished by buffalo calves along with maize and rice bran for over 150 days (Reddy, 1992). Further, both NaOH (1 and 2%, wt/wt) and urea (1.5 and 2.5%, wt/wt) at reduced rates employed successfully for debitterising NKM by Nagalakshmi (1993) in feeding of broiler chicks.

**LIVESTOCK PERFORMANCE**

**Ruminants**

1) Large ruminants

Bedi et al. (1975a, b) reported poor palatability accompanied by either depressed weight gain or loss of body weight along with lowered nutrient digestibility in crossbred calves fed concentrate mixture containing NSC to contribute 12.5, 25 or 50% of DCP requirement suggesting the NSC as such was unsuitable for animal feeding even for maintenance. Protein utilization was adversely affected in buffalo calves (Arora et al., 1975) and crossbred ball calves (Pradhan, 1975) due to feeding of NSC, respectively. The nimbin derivatives of neem though did not adversely affect rumen microbial protein synthesis in buffalo calves on feeding 20 parts of NSC, it severely depressed intake of feed and growth (Ludri and Arora, 1977). However, Mondal et al. (1995) reported lowered rumen protozoal count along with reduced enzyme activity in calves fed NSC. On the otherhand, presence of albumin and bile salts in the urine of cattle fed on concentrate mixture containing 10 and 20 parts of NSC indicating impaired protein metabolism (Anon, 1977-78). A short term (60 days) feeding trial of 10, 15 and 20% NSC included concentrate mixture to lactating buffaloes did not alter the milk composition and general health of the animals. However, RBC, WBC and haemoglobin levels were lower on NSC ration than control fed animals (Pyne et al., 1979). Safe incorporation of NSC upto 20% in concentrate mixture was suggested by Gangopadhyay et al. (1981) basing on the unaltered GOT and GPT activities and blood Ca and P levels. Inspite of higher DM intake to compensate 17% low TDN availability severe growth depression (46%) along with lowered blood haemoglobin, higher GPT and similar GOT, alkaline phosphatase and cholesterol was observed in crossbred calves fed 45% DNMC as compared to that in control ration fed calves (Garg, 1989). The NSC extract was tried as an antifeedant to desert locusts and the oily residue of alcoholic unlike KOH or NaCO₃ extract was found less effective against aphids (Sinha and Gulati, 1964). Therefore it was presumed that alkali treatment of NSC could make it palatable probably due to neutralisation of bitter principles. It was also shown that overnight soaking of NSC in 1% NaOH solution followed by water washing removed the bitter principles (Anon, 1977-78). Boiling of NSC with NaOH (8 g/kg cake in 2.5 lit. water) for 30 min. and removal of solubles through water washing yielded a product palatable to cattle (Nath et al., 1978), and DM intake on 50% of such treated NSC incorporated concentrate mixture was comparable to control with low digestibility and growth rate due to lesser available energy in a 50 days feeding trial. Vijjan et al. (1978) did not observe any ill effect of alkali treated NSC (ATNSC) on creatine excretion in urine. Similar DM intake, digestibility, balance of Ca, P but depressed growth rate were observed in cow calves fed concentrate mixture containing 45% ATNSC (Rao and Nath, 1979). Serum icteric index, inorganic phosphorus and alkaline phosphatase activity also were similar between control and experimental groups. A significantly (P<0.05) low haemoglobin content in ATNSC fed calves, however indicated that alkali treatment did not remove the toxic bitters completely though it was palatable to calves. 

Though NKC is rich in protein with low fibre than NSC, its incorporation at 45% level in the concentrate mixture severely depressed the growth rate in crossbred bull calves without any affect on intake and nutrient digestibility (Rajgopal and Nath, 1981). Nath et al. (1983) attempted water washing of NKC after
overnight soaking in NaOH (0.8%, wt/wt) followed by repeated draining off with two or three times water washing. Such water washed NK (WNK) when incorporated after sundrying at 45% level in the concentrate mixture of bull calves for 273 days resulted in significantly lower growth rate with comparable DM intake, nutrient digestibility, balances of Ca, P, N and TDN intake. The blood haemoglobin, serum acid phosphatase, GOT and GPT also did not differ indicating that water washing largely removed the bitter. In an another experiment, Agrawal et al. (1987) observed significantly (p<0.01) lower DM digestibility but higher N- balance and faster growth of buffalo calves fed 40% WNK than in those on control diet. Incorporation of 40% WNK in dairy concentrate mixture for 300 days revealed no significant variation in milk yield, fat %, sensory evaluation of milk and DM intake and its digestibility (Nath et al., 1989). Blood haemoglobin, serum enzymes and reproductive ability of the cows were also not disturbed.

Though water washing of NSC/NKC did improve its palatability, the process was not feasible owing to the loss if nutrients in washing. Realising this, Katiyar et al. (1991) developed a simple method for debitterization through alkali soaking or urea-ammoniation without water washing. Such alkali (2.5%, wt/wt NaOH) soaked and urea (3.5%, wt/wt) - ammoniated NK (ATNK/UNKC) at 30 parts of inclusion in the concentrate mixture of buffalo calves for 150 days feeding revealed comparable feed intake and utilization (Reddy, 1992). Sensory evaluation of meat and gross pathological examination of vital organs also did not show any abnormalities.

2) Small ruminants

In small ruminants also few feeding trials with NSC/NKC were conducted. Replacing 100, 75 and 50% peanut meal (PM) protein with DNSC in the lamb diet resulted in a daily body weight loss of 214, 176 and 147 g, respectively within 21 days as compared to a gain of 176 g in lambs on control diet (Bhandari and Joshi, 1974). Toxicity symptoms such as stomatitis, severe gingivitis and sloughing of tongue epithelium and mucosa together with foamy discharge from the mouth were observed after 15 days of feeding DNSC diet. Gastroenteritis and diarrhoea resulted in death after 25 days of feeding. Gupta and Bhard (1981) also observed decline in growth rate (66, 58 and 8 g/day) of lambs with increase in levels (50, 75 and 100%) of neem fruit cake during 4 months of experimental feeding. Vijan et al. (1982) studied the effect of feeding raw as well as alcohol extracted NSC at 10, 20 and 30% level substituting the wheat bran of concentrate mixture in lambs. Lower levels (10 and 20%) of NSC/alcohol extracted NSC incorporation resulted in respectively comparable and improved growth rates, while 30% inclusion of both the cakes led to body weight loss, especially with the raw cake. Blood glucose, haemoglobin and urea were similar in all the groups with no appreciable changes in organ weights and their histopathology even at 30% of NSC inclusion. Incorporation of WNK in the concentrate mixture of male kids at 15 and 25 parts for 180 days of feeding led to comparable intake and utilization of nutrients, besides normal balance of nitrogen, urinary creatine, blood haemoglobin, cholesterol and activities of GOT, GPT and alkaline phosphatase with lowered (p<0.01) blood glucose, urea and total protein (Verma et al., 1995). Similarly Anandan et al. (1999) also recorded no untoward effect in kids due to feeding of urea ammoniated NK (UNKC) for similar period of feeding. However on similar UNKC diet lambs digested the DM, OM and NFE significantly (p<0.05) lesser with comparable balance of nitrogen and depressed (p<0.05) Ca and P retentions (Musa et al., 1999). Further UNKC had low (p<0.05) digestive energy and the lambs compensated the energy requirement through higher intake of hay, culminating in similar growth and feed conversion efficiency and long term feeding did not affect the blood biochemical profile, meat or wool quality. Rumen study indicated depressed (p<0.01) total volatile fatty acids and total nitrogen accompanied with lowered (p<0.05) cellulase, protease and urease with unaltered amylase activities.

Monogastries

Adverse effect on growth and feed efficiency was shown in White Leghorns chicks fed deoiled neem seed meal (DNSM) at or above 5% level for 8 weeks (Subbarayuddu and Reddy, 1975). Studies with Bobcoock cockrocks fed DNSM for 4 months resulted in comparable feed intake but passed reddish brown, fluidy faeces with gradual and progressive emaciation, pale and shrunken muscles with serious subcutaneous fat (Christopher et al., 1976). Histologically liver and kidney showed extensive fatty changes and the testis showed sluggish spermatogenesis. Chicks had poor growth and nutrient utilization on feeding raw NSM and water soaked NSM at 30% level for 6 weeks (Choudhary et al., 1981). Similarly, Sadagopan et al. (1981) also recorded reduction in weight gain of broiler chicks fed raw NSM at 2.5, 5 and 7.5% level but solvent extraction of NSM improved the growth rate. In a similar experiment the same researchers replaced the peanut meal at 25, 50, 75 and 100% levels with NSM in layer diet and observed a progressive decline (p<0.05) in egg production at higher level of replacement with unaffected egg weight and quality.

Toxicity and degenerative changes in liver and
kidney were reported in birds fed water extracts of neem fruits (Singh et al., 1985). Undecorticated expeller neem cake at 10% of broiler chicks diet depressed (p<0.05) weight gain while feed efficiency was reduced at 20% level of inclusion and the growth inhibition was linearly pronounced with the corresponding increase in level of incorporation (Reddy and Rao, 1988a). Whereas, incorporation of double solvent (ether followed by ethanol) extracted undecorticated NSC improved its utilisation (Reddy and Rao, 1988b). Further overnight acid (1 N HCl) followed by alkali (5% KOH wt/vol) soaking for 15 min. with water washing in between each treatment of solvent extracted undecorticated neem cake removed the bitterness as indicated by comparable feed intake, growth and feed efficiency of chicks (Reddy and Rao, 1988c). Similarly saponification of neem oil with 10% KOH completely detoxified the oil as evidenced by comparable performance of broiler chicks fed saponified neem oil and peanut oil (Reddy et al., 1988a). Chand (1987) fed diets having either 10, 20 and 30% raw NSM or its equivalent 0.9, 1.8 and 2.7% neem oil to chicks and recorded poor growth and low feed efficiency and inclusion of alcohol and hexane extracted NSM though improved the utilization, found unsuitable beyond 30% level of incorporation. Gross pathological examination of visceral organs revealed pale liver with thickened borders and catarhal inflammation of intestine including the birds fed 30% solvent extracted meal. Incorporation of alkali treated and urea-amomiated NKM in broiler chick diets indicated comparable performance at 50% replacement of peanut meal and carcass traits as well as sensory evaluation of meat did not exhibit any untoward effect (Nagalakshmi, 1991). Broiler chicks fed full fat NSM (FFNSM) 2.5, 5, 7.5 and 10% of dietary level showed a significant (p<0.05) negative correlation between the level of inclusion, weight gain and feed conversion efficiency during the starter phase (0-5 wk), whereas birds in finisher phase (6-10 wk) exhibited comparable performance probably due to the colonization of counteracting gut microflora (Salawu et al., 1994) and gross pathology of visceral organs did not reveal any abnormalities. Similarly, Verni et al. (1998) also recorded no adverse effect of feeding raw or pretreated (2% NaOH) NKM at 10% of dietary inclusion on feed consumption, egg production, egg weight, internal quality, yolk colour, shell thickness and organoleptic evaluation of boiled eggs during a 12 wk period of laying. However, raw NKM at levels of 15 and 20% dietary inclusion adversely affected the performance in layers (Gowda et al., 1988c). Birds fed diet with 20% of NKM inclusion showed degenerative changes in ovary with loss of ovarian follicles and histological changes in liver, kidney and intestine (Gowda et al., 2000). Similarly, water washed NKM (WWNK) in the diet of cockerels at 20% level for a period of 12 week adversely affected the spermatogenesis and fertility (Tyagi et al., 1996), confirming the anti-fertility effect of neem.

Studies with neem cake or its derivatives in other monogastric animals are also available. Desi pigs fed 10% WWKNC included diet for a period of 180 days grew faster (p<0.05) and utilized the feed and protein efficiently (p<0.05) with higher (p<0.05) nitrogen retention which reduced the cost of pork production by 11% (Sastry and Agrawal, 1992) and the sensory evaluation of pork of those animals revealed no bitter taste (Sushil Kumar et al., 1989). Vijian and Parthasarthy (1983) fed diets of 10% NSC and alcohol extracted NSC to rats for 60 days and recorded poor growth, pronounced testicular degeneration with arrest of spermatogenesis in rats fed NSC and milder lesions in those fed alcohol extracted NSC. Hepatic microsomal enzyme inhibition was reported by Vijian and Tandon (1985) due to feeding water extract of NSC to rats. Feeding of raw NKC, WWKNC and solvent extracted NKC at 14% level to rats revealed significantly (p<0.05) lowered feed intake, weight gain, weight of testis and sorbitol dehydrogenase activity indicating a sluggish spermatogenesis (Garg et al., 1984).

Feeding of neem seed meal as a protein source for rabbits was also attempted by few researchers. Rabbits fed diets containing 10, 20 and 30% raw NSM resulted in similar performance till 20% and reversed at 30% level (Fuzinimi et al., 1989). Similarly, full fat neem seed meal (FFNSM) at 10 and 20% inclusion level resulted in superior (p<0.05) and similar performance than control, respectively but 30% level showed poor (p<0.05) performance (Salawu et al., 1994). Vasanthkumar et al. (1995) also observed lowered feed intake, nutrient digestibility and growth in rabbits fed 20% raw NSM in a composite diet for 12 wk period. In contrast to the above, Khan (1994) noticed comparable growth performance with similar carcass characteristics in rabbits fed alkali (2.5% NaOH, wt/wt) treated NKM (ATNKM) or WWKNM to those rabbits on soybean or mustard meal diets. Dehydration of NKM with reduced NaOH (1.5%, wt/wt) soaking or urea (2%, wt/wt)-ammoniation of NKM and incorporation into a composite diet of rabbits in a long term (18 wk) feeding trial revealed moderate increase in goblet cell activity, mucosal thinning and fibro-cellular reaction in liver and kidney. Higher level of processed NKM feeding also resulted in accumulation of pinkish homogenous fluid with mild disorganization of spermatogonial cells, vacuolation and clumping. But these changes failed to alter the sensitive serum transaminases, blood haemoglobin, protein and urea-N levels and on the other hand growth, nutrient utilization, feed efficiency, caecal fermentation and carcass characteristics including
sensory evaluation of meat were comparable to reference rabbits (Gowda et al., 1996, 1997a and 1998a, b). This indicated the cumulative effect of residual neem bitters. However, none of the above histopathological lesions could be noticed in lambs or goats fed urea (2.5%, wt/wt) ammoniated NKM at 33% level in the concentrate mixture for over an year (Mahanta et al., 1995; Musalia et al., 1999), and hence a possible involvement of rumen microbes in the degradation of residual neem bitters cannot be ruled out as in the case of gossypol (Hungate, 1966) and mimostine (Kumar et al., 1987).

**Hypoglycaemic effect**

Anti-hyperglycemic action of neem bitters has been studied by several researchers. Pillai and Santa Kumari (1981) observed a significant (p<0.01) hypoglycaemic activity of 24 and 26% due to feeding neem oil at 2.5 ml/kg and nimbidin at 200 mg/kg to fasting rabbits, respectively. A maximum of 27% glucose reduction within 3 hrs of oral administration of 200 mg/kg of 10% aqueous extract from tender neem leaves was observed in guinea pigs (Murthy et al., 1978). Such hypoglycaemic findings were also reported in dogs (Bhargava et al., 1985) and rats (Dixit et al., 1986).

**CONCLUSIONS**

Realization of a practical processing technology to make neem cake wholesome for animal feeding at higher level appears to be attained. Such a methodology needs to be tested and perfected for maximum debitterization of NSC/NKC/NKM with minimum cost. Analytical procedures for neem toxicants involves sophistication, besides costly and time consuming. Hence, the best alternative is bioassay with fast growing species of animals. Removal of neem fruit pulp and seed coat needs to be done effectively in oil industry for better oil recovery. Thus resultant decorticated and nutritious neem kernel residue will definitely fetch a better market price and play a positive role in mitigating the chronic shortage of proteinic feeds.

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