



## Non-conventional meals and cakes in ruminants

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### ABSTRACT

A comprehensive review on nutritive value of non-conventional meals and cakes, viz. sal seed meal, neem cake, castor oil cake, karanj cake, rubber seed meal, guar meal and palm kernel cake, their safe levels of inclusion in ruminant diet and various processing methods for their detoxification was carried out. CP content in above feeds was well above 20% except sal seed meal (14%). Among several methods water washing, soaking, steam cooking, chemical and biological methods were the most abundantly tried by the researchers. Chemical treatment was effective in reducing toxic principles from sal seed meal (80–90%), neem seed cake, castor oil cake (around 100%) and karanj cake. In several cases, water washing after chemical treatment resulted in huge loss of dry matter (DM). Biological treatment with fungal culture was successful for the safe inclusion of guar meal and rubber seed cake. Thus non-conventional ingredients on detoxification hold a great promise in reducing the competition for feedstuff among human and ruminants and also in balancing ruminant ration.

**Key words:** Detoxification, Meals, Non-conventional, Oil cakes, Ruminants

The yields from livestock as well as other production traits are directly related to the food availability to animals. In the changing scenario of increasing livestock population the demand for feed and fodder is growing proportionately. But the simultaneous increase in the human population has made lesser availability of land for fodder crops cultivation and grazing. There was a shortfall of green and dry fodder by 666 and 138 million tonnes respectively in the year 2010 which was predicted to increase to 696 and 143 million tonnes by 2015 (X Five Year Plan Document, Government of India). The increased gap between necessary and available feed is due to improper use of existing feed resources. Few specific by-products like cakes, hulls, chunies, baggasses, tops, molasses etc. produced during processing of agricultural materials are accepted for use in animal feeds, thus solve feed scarcity issue to some extent (Sharma *et al.* 2012a and 2012b; Swain *et al.* 2016). Yet other by-products not general in use in livestock feed otherwise known as non-conventional feeds are produced on large scale in specific regions of India. One foremost factor limiting their use is presence of particular anti-metabolites/ toxic principles in them. With an aim to reduce the large difference between the availability and necessity

of animal feed-researchers conducted experiments to include those non-conventional feeds in livestock ration after either removal or reduction of the toxic principles. Their inclusion in livestock feed would further lead to low cost animal rearing. There are large quantity of seeds available from non-edible plants in India which are processed in industry either for extraction of oil or gum leaving huge quantity of residue as cakes and meals. Oil extracted from seeds of karanja (*Pongamia pinnata*), mahua (*Madhuca indica*), castor bean seed (*Ricinus communis*), neem (*Azadirachta indica*), sal (*Shorea robusta*) and rubber (*Hevea brasiliensis*) are used in cosmetics, lubricants, medicines, biodiesel, insecticides and pesticides etc. Oil content of these seed ranges from 27–39%, 30–45%, 48–60%, 25–45%, 14–15% (fat) and 40–50%, respectively (Demirbas *et al.* 2016). Guar seed is processed exclusively for manufacture of guar gum producing guar meal as by-product. The present review reported chemical composition and nutritive value of sal seed meal, neem cake, castor oil cake, karanj cake, rubber seed meal, guar meal, palm kernel cake and various detoxification methods adapted to for their safe inclusion in ruminant ration in tropics.

*By-products and their availability:* Sal (*Shorea robusta*) belongs to the family Dipterocarpaceae. Sal seed meal (SSM) is a by-product of the sal seed fat industry in India and its availability is of the order of 0.7 lakh metric tonnes/annum (Kundu *et al.* 2005).

Neem (*Azadirachta indica*) belongs to family Meliaceae and Neem seed cake (NSC) is the residue obtained while extracting neem oil from neem seed kernels by cold pressed

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extraction. In India, around 0.4 million metric tonnes of neem seed cake (NSC) is produced annually (Radhakrishna, 2003).

Castor (*Ricinus communis*) belongs to the family Euphorbiaceae. India is the 2<sup>nd</sup> largest producer of castor bean followed by Brazil. Annual production of castor in India is 590,000 tonnes (FAO, 2002). Castor cake is the residue left after the extraction of the oil from castor bean, representing about half of the weight of the castor bean.

Karanj (*Pongamia glabra* or *Pongamia pinnata*) belongs to the order Leguminosae and family Papilionaceae. The karanj seed is popularly known as Indian beech. The cake is obtained from the solvent extraction of the seed. Production of karanja seed is around 0.56 lakh tonnes/annum against potential of 2 lakh tonnes/year (Chandra *et al.* 2006)

Rubber seed cake (RSC) is prepared from rubber (*Hevea brasiliensis*) seed by pressing or ether extraction. The rubber seed shell is first decorticated and then subjected to heat treatment (20 mins) before oil extraction to get RSC. Annual rubber seed production potential in India is about 150 kg/ha (Reksowardojo *et al.* 2011). Availability of RSC was 1.5 lakh metric tonnes as reported by Kundu *et al.* (2005).

Mahua (*Madhuca indica*) is a very useful tree widely distributed in the forests of India. The two major species of genus *Madhuca* found in India, viz. *Madhuca indica* (syn. *Bassia latifolia*) and *Madhuca longifolia* (syn. *Brassica longifolia*). *Madhuca latifolia* can be raised with agricultural crops. Leaves, flowers and fruits are offered to goats and sheep. Mahua seed cake (MSC) is also fed to cattle besides being used as a fertilizer. The cake is obtained after extraction of oil from the seed by either expeller or solvent extraction. The yield of Mahua seed varies from 5 to 200 kg/tree depending upon the size and age of the tree. The amount of oil extracted is 34–37% weight of kernels in expellers and 40–43% when extracted by solvents. The total availability of the cake was 3 lakh metric tonnes as reported by Kundu *et al.* (2005).

Guar (*Cyamopsis tetragonoloba*) is a drought-tolerant *kharif* legume grown chiefly in arid and semi-arid areas like Gujarat, Rajasthan and some part of Haryana during monsoon. In Asia, guar bean is also used as a vegetable for human. Guar meal is the main by-product of guar gum production. It is a mixture of germs and hulls at an approximate ratio of 25% germ to 75% hull (Lee *et al.* 2004).

Palm kernel cake (PKC) or palm kernel meal is obtained after extraction of oil as a by-product from the oil palm industry and is readily available in tropical countries at cheap prices. The yield of palm oil had increased from 5 to 6 thousand million tonnes from the year 2002 to 2012 (USDA report). So, an increasing trend in this cake production is obvious. But not much work had been carried out for its use in animal ration.

#### Nutritive value and inclusion in feeds

*Sal seed meal:* DE and ME (Mcal/kg TDN) value of

SSM was 2.28 and 1.86, respectively whereas TDN of deoiled sal seed meal (DSSM) was 47.2% in goat (Khan *et al.* 1986). Higher intake has been reported on feeding DSSM based concentrate to goat compared to crushed maize, but lead to lower nutrient (DM, CP, CF, EE and NFE) digestibility (Table 1). Concentrate with 70% DSSM showed no adverse effect on growth rate and digestibility of nutrients (Rajagopal and Nath, 1983) or milk yield and composition (Hasan *et al.* 1983) compared to control. Bhakt *et al.* (1997) recommended a safe inclusion of 20% of urea treated DSSM in the concentrate mixture of growing male calves without adversely affecting growth rate, animal health and feed intakes. Higher levels of inclusion (30%) of deoiled sal seed meal in growing calves ration, did not affect animal health, intake and performance in a study by Garg *et al.* (1984). Rai and Shukla (1979) studied the effect of inclusion of deoiled sal seed meal at 0, 10 and 20% levels on milk yield, its composition and utilization of various nutrients. The data did not reveal any significant effect on body weight changes, feed consumption, milk yield and its composition. The protein digestibility was depressed but the digestibility of other nutrients was practically unaffected.

*Neem seed cake:* Neem seed cake (NSC) is balanced in Ca and P and is exceptionally high in K and Fe and consists of all Essential Amino Acids (EAA) and non-EAA but is a poor source of histidine, lysine and tyrosine (Gowda and Sastry, 2000). Garg and Nath (1990) reported higher DM intake in crossbred calves on diet consisting concentrate mixture with 45% NSC compared to control. Higher DM intake has been reported in lambs on urea treated neem seed kernel cake (UTNSKC) based diet at 22.5% level compared to ground nut cake (GNC) based diet on iso-nitrogenous basis (Musalia *et al.* 2000). In another study, lowered digestibility and P retention was observed in lambs when UTNSKC at higher level (33% of concentrate mixture) replaced GNC on protein equivalent basis (Musalia *et al.* 2002). Feeding pelleted NSC based diet led to higher DCP (10.9 g/kg DM) and TDN in Nellore sheep (Madhavi *et al.* 2006). Extensive review of the scopes and limitations of neem seed cake in animal feeding have been done by Gowda and Sastry (2000).

*Castor oil cake:* Protein content of decorticated castor cake goes up to 50% and thus, it can be a good source of protein for animals. There was higher concentration of soluble proteins (albumin and globulin) in castor cake than GNC and mustard cake (Wadhwa *et al.* 2010). The 48 h CP degradability of castor oil seed cake was 98% comparable to that of GNC (98%) and mustard cake (94%) (Wadhwa *et al.* 2010). Anandan *et al.* (2005a) reported very low (<49%) IVOMD of castor cake as it was rich in lignin (>35%). Non-detoxified castor meal could be incorporated at 5% of total ration for cattle (Robb *et al.* 1974).

*Karanj cake:* Karanj cake has TDN and DCP value of 93.1% and 20.8%, respectively in sheep (Chandrasekaran *et al.* 1989). Long term feeding of Karanj cake had deleterious effects on nutrient utilization, blood biochemical

Table 1. Nutrient composition of non-conventional meals and cakes on percentage DM basis

Ingredient	CP%	EE%	Available CHO%/ Soluble CHO%*	CF%/ NDF% <sup>@</sup>	NFE%	Ash%	Reference
Sal seed meal	14			37.97 <sup>@</sup>			Barman and Rai, 2004
	9.5	10.73		1.9	74.55	3.32	Pal <i>et al.</i> 1973
Deoiled sal seed meal	10.21	1.69		3.57	80.33	3.7	Sinha and Nath, 1982
Neem seed cake (NSC)	41.3	3.5	–	0.51	40.69	14	Mubarak <i>et al.</i> 2012
	31.5	6.4	10.7	4.1		5.3	Djenontin <i>et al.</i> 2012
Water soaked NSC	17.48	4.12	–	19.59	38.73	9.82	Odunsi <i>et al.</i> 2009
Deoiled NSC	17.86	0.39	–	30.21	35.22	16.32	Garg and Nath, 1990
Neem seed kernel cake	40.33	8.46	–	15.38	19.33	16.5	Musalia <i>et al.</i> 2000
Castor cake	29–35	–	–	39–46	–	–	Anandan <i>et al.</i> 2005
	19.4–49.3	2.6–3.1		11.6–33.1		7.2–14.8	Lacerda <i>et al.</i> 2014
	38.58	11.15		3.46	32.6	5.87	Akande <i>et al.</i> 2012
Castor bean cake expeller	31.82	5.40		55.06 <sup>@</sup>		6.47	Kumar <i>et al.</i> 2007
Castor bean cake solvent extracted	33.81	0.86		49.65 <sup>@</sup>		12.33	Kumar <i>et al.</i> 2007
Un-decorticated full fat castor seed meal	20.78	51.2	7.96*	4.98	–	7.75	Annongu <i>et al.</i> 2008
Un-decorticated castor seed cake	31.06	19.4	24.69*	11.9	–	11.1	
Decorticated full fat castor seed meal	21.87	55.5	8.86*	2.5	–	9.4	
Decorticated castor seed cake	35.43	25.1	24.88*	4.43	–	7.14	
Expeller extracted karanj cake	20.62	7.66	25.80*	27.17	39.94	4.61	Prusty, 2011
Expeller extracted karanj cake	29.71	6.88		39.92 <sup>@</sup>		6.13	Kumar <i>et al.</i> 2007
Solvent extracted karanj cake	26.90	1.70	19	5.50	60.2	5.70	Natanam <i>et al.</i> 1989
Solvent extracted karanj cake	32.87	0.98		33.39 <sup>@</sup>		5.94	Kumar <i>et al.</i> 2007
Decorticated Rubber seed cake	32.98	10.12	–	4.20		6.21	Madubuike <i>et al.</i> 2006
Expeller Mahua cake	17.82	5.02		9.55	59.27	8.34	Joshi <i>et al.</i> 1984
Solvent extracted Mahua cake	19.4	0.14		9.9	61.64	8.93	Joshi <i>et al.</i> 1984
Guar meal	53	4	–	30.29 <sup>@</sup>	33.6	6.5	Goswami <i>et al.</i> 2012
Palm kernel cake	16.42–21	7.83–9.4	–	–	–	4.52	Chanjula <i>et al.</i> 2011

\*soluble carbohydrate; @neutral detergent fibre

profile, rumen fermentation pattern, carcass characteristics which was manifested by clinico-pathological changes in bone and tissues of vital organs of sheep (Singh *et al.* 2006). Kumar *et al.* (2011) observed no adverse effect on rumen fermentation on supplementing Karanj seed meal (KSM) sole nitrogen source in the concentrate mixture. But another study reported pathological changes in liver, kidney and testes of KSC fed lambs were observed karanj seed cake was offered as sole protein source replacing GNC in the complete diet (Nagalakshmi *et al.* 2012). Srivastava *et al.* (1990) observed a decline in protein digestibility in growing goat kids, fed on diet with 40% of solvent-extracted cake. The protein rich non-conventional detoxified karanj cake (dKC) can be used in place of conventional protein supplements like soybean meal (SBM), groundnut meal, etc. in livestock feed. Prusty *et al.* (2013) reported higher soluble sugar and organic acid, starch and pectin content in karanj cake compared to routinely used cakes. In ram lambs, Dinesh kumar *et al.* (2013) observed that long-term feeding of dKC on 50% replacement of SBM did not affect body weight but affected testicular function, whereas a drop in semen production capacity and insulin like growth factor-1 (IGF-1) expression at 75% replacements was observed.

**Rubber seed cake:** Rubber seed cake is higher in the essential nutrients than soybean meal and is highly promising as a protein supplement (Eka *et al.* 2010). It has a high level of tryptophan, but is poor in lysine (Ensminger and Olentine, 1978). Compared to maize it is rich in lysine (4.26, 2.9 mg/16 g N, respectively) phenylalanine (4.88, 4.6 mg/16 g N, respectively) and valine (7.08, 5.3 mg/16 g N, respectively). Hevea brasiliensis oil is rich source of essential fatty acids C18:2 and C18:3 that make up 52% of its total FFA composition (Salimon and Abdullah, 2009). A level of 20% inclusion of RSC for 200 days in concentrate mixture of fattening goats without any adverse effect has been reported (Rajan *et al.* 1990). An inclusion of up to 20% of un-defatted rubber seed meal was recommended in sheep ration (Njwe *et al.* 1990). Replacement of GNC (15% of diet DM) with stored RSC showed very good growth rate (116 g/d) in goat (Hao and Liem, 2003). In an *in sacco* experiment Sampath and Sivaraman (1985) found out DM and protein disappearance of RSC and GNC at 24 h of incubation to be 73.77% and 96.28%, respectively and both showed similar protein degradability as well, i.e. 68.61% and 66.76% respectively. Above finding suggest RSC as a poor source of bypass protein.

**Mahua cake:** Mahua seed cake (MSC) is poor in essential amino acids arginine and tryptophan (Rao *et al.* 2013). Varma and Singh (1979) treated MSC in water (1:4) and stirred repeatedly till separation of foam and appearance of oily and yellowish foam. On supplementing the above cake to meet 50% of total DCP requirement of cross-bred dairy calves they observed no adverse effect on their growth rate. The digestibility was not affected on replacing 100% of GNC with water treated expeller pressed mahua cake in lactating buffaloes (Tiwari and Patle, 1997).

**Guar meal:** The meal is very rich in protein. The methionine and lysine content of guar meal were comparable to that of GNC (Goswami *et al.* 2012). Inclusion of guar meal at 5% level in complete feed block of cross bred calves showing average daily growth of 600 g/day showed similar intake, digestibility, average daily gain and feed conversion ratio compared to control (Sharma *et al.* 2012). Inclusion of guar meal at 10% level in the concentrate mixture in replacement of GNC showed better average daily gain and feed conversion ratio in growing crossbred calves (Ojha *et al.* 2013). Replacement of GNC with guar meal at 50% level in concentrate mixture of growing crossbred calves had no adverse effect on the growth and was economical as well (Goswami *et al.* 2012). As a protein supplement Guar meal had better digestibility coefficient and caused early sexual maturity in Murrah male calves compared to GNC (Lohan *et al.* 1989). Jongwe *et al.* (2014) conducted a study in Sahiwal cows replacing GNC with Guar meal at 75% level in the concentrate mixture without added sweetener or flavour and reported no significant difference in the digestibility coefficients (%) for DM, OM, CP, EE, NDF and ADF.

**Palm kernel cake:** Cattle fed on PKC as supplements or basal diets showed improved growth performances (Jelan *et al.* 1991). Inclusion of more than 20% PKC in the diet of goat did not affect feed intake, digestibility, rumen fermentation patterns, blood metabolite profiles and nitrogen utilization (Chanjula *et al.* 2011). PKC at 20–30% in concentrate was efficiently utilized in goats fed along with signal hay (Chujai *et al.* 2011). Overall mean ruminal pH (6.28–6.14) and  $\text{NH}_3\text{-N}$  (16.31–17.74 mg/dl) were within the normal ranges which have been reported as optimal for microbial digestion of fiber. Total tract apparent digestibility of DM, OM and CP were 73.36%, 74.43% and 70.93% for 20% inclusion and 73.48%, 74.44% and 73.97% for 30% inclusion.

#### *Anti-nutritional factors in by-products and their detoxification*

**Sal seed meal:** The presence of tannins (6.2–13.7%) in SSM limits its use in concentrate mixture (Table 2) as it adversely affects the utilization of other feed proteins in ruminants (Kurar and Gupta, 1982). Lata *et al.* (2012) found negative correlation between tannin concentration and *in vitro* DM, OM, CP degradability and *in vitro* gas production as well. Treatment with 5%  $\text{Ca}(\text{OH})_2$  for 24 h lead to 100% reduction of tannin in SSM (Singh and Arora, 1978).

Mahmood *et al.* (2007) reported 83% detannification of SSM on incubation with alkali for 72 h. Detanning of deoiled sal seed meal (DSSM) with sodium carbonate solutions at various concentrations removed 78 to 90% tannin. But water washing of SSM followed by chemical treatment, viz. sodium hydroxide and sodium carbonate resulted severe DM (20–71%) loss (Rao and Rao, 1986). Polyvinyl polypyrrolidone (PVPP) was also found effective in removing more than half the tannin of SSM (Mahmood *et al.* 2007). From the above methods calcium hydroxide treatment for 24 h made SSM fully devoid of tannin whereas Sodium carbonate solution was effective up to 90%. But treatments inclusive of water washing caused great loss of DM (up to 70%). Since  $\text{NaHCO}_3$  is around half the cost of NaOH there is scope for its use in detannification on commercial scale. An extruded product 'salurea-90' was prepared by Reddy and Prasad (1987) by adding 95 ml water to 1 kg of finely ground DSSM and urea (74: 26) by S-40 L cooker extruder, at a screw speed of 350 rpm, die size of 6 mm and an exit temperature of 116–120°C and then cutting into 1.5 cm pieces and drying at 70°C. That product had 16% moisture and was superior to unprocessed urea and DSSM and was equivalent to GNC protein value with regard to N retention in sheep.

**Neem seed cake:** Certain detrimental factors in neem like azadirachtin, salanin, trypsin inhibitor etc. affect the digestibility adversely (Rao *et al.* 2013). Garg and Nath (1990) observed 17% lower TDN and 46% lesser growth rate in 6–9 months old calves on feeding solvent extracted neem seed cake (NSC) based ration for 75 days compared to control, though the intake was not adversely affected. They also reported lower calcium balance in the NSC group as the detrimental factor in NSC might have affected Ca metabolism. Several detoxification methods were adopted by different workers for a safe inclusion of NSC in the animal ration. Alkali-treated NSC removed the toxic principles of neem seed cake almost completely and had no adverse effect on health and growth rate of cattle (Katiyar *et al.* 1993). Intake of sun-dried and ground alkali treated as well as sun-dried and ground urea ammoniated neem seed kernel cake had no adverse effect on growth, nutrient utilization, blood profile, rumen fermentation pattern of small ruminants (Musalia *et al.* 2000). On feeding water washed and urea-ammonia treated NSC based ration at 15% no deleterious effect on growth and meat quality of sheep was observed (Madhavi *et al.* 2006). Inclusion of water washed NSKC at 35% level in concentrate mixture did not affect nutrient intake and digestibility in crossbred male calves (Mondal *et al.* 1997). Later Kumar and Reddy (2004) reported that water washing removed 82.53% of azadirachtin, 53.13% of nimbin and 35.89% of salannin and chemical treatment (4% urea with 40% moisture) removed 45.5% azadirachtin, 75.94% nimbin and 98.07% salannin whereas water washing followed by urea treatment removed 83.27% azadirachtin, 100% nimbin and salanin of NSC. Among hexane or alcohol extraction, water washing and alkali treatment (0.8%) methods water washing was

Table 2. Level of inclusion, toxic principles and detoxification methods of the non conventional meals and cakes

Ingredient	Inclusion levels	Toxic principles	Detoxification method
Deoiled sal seed meal (DSSM)	30% in conc. mix. of growing calves. 20% urea treated DSSM in conc. mix. of growing calves	tannin	<ul style="list-style-type: none"> <li>• 0.1N NaOH treatment</li> <li>• 5% Ca(OH)<sub>2</sub> treatment</li> <li>• Sodium carbonate solution</li> <li>• PVPP treatment</li> <li>• Aqueous ethanol (505 v/v)</li> <li>• Cooking followed by extraction with 90% ethanol</li> </ul>
Water washed neem seed kernel cake	35% in conc. mix. of male crossbred calves. 15% in complete diet of sheep	azadirachtin, nimbin and salannin	<ul style="list-style-type: none"> <li>• Sun dried and ground alkali treatment</li> <li>• Water washing</li> <li>• Soaking with alkali solution (NaOH, 2% w/w) at 20% w/v</li> <li>• ensiling with 2.5% urea (w/w)</li> </ul>
urea-ammonia treated NSC	15% in complete diet of sheep		
Castor cake	Detoxified castor cake at 10% in lactating Mehsana buffalo ration	ricin, ricinine, allergen	<ul style="list-style-type: none"> <li>• Autoclaving (15 psi. 60 min)</li> <li>• Lime treatment (40 g/kg)</li> <li>• Micro processed calcium oxide at concentration of 60g/kg</li> <li>• Soaking over-night in 0.5% Ca(OH)<sub>2</sub></li> <li>• autoclaving and soaking in 0.5%NaHCO<sub>3</sub> solution</li> </ul>
Deoiled karanj cake	24–30% of concentrate mix. in growing calves	karanjin, tannin and trypsin inhibitor	<ul style="list-style-type: none"> <li>• Solvent extraction</li> <li>• Pressure cooking</li> <li>• 3% (w/w) Ca(OH)<sub>2</sub>)</li> <li>• Lime (1 and 2.5%)</li> <li>• Sodium hydroxide (2.5%)</li> <li>• hydroxy sodium calcium aluminosilicate (HSCAS) (0.1%)</li> </ul>
Un-defatted rubber seed meal	20% in sheep ration	Cyanogen, tannin	<ul style="list-style-type: none"> <li>• Biological treatment with mushroom mycelium for 96 h at room temperature</li> <li>• Storage at room temperature for a minimum period of two months</li> </ul>
Mahua cake	Detoxified MSC at 20% of concentrate mix. in sheep ration	mowrin	<ul style="list-style-type: none"> <li>• Alkali treatment–</li> <li>• Ensiling with urea</li> </ul>
Guar meal	5% in complete feed for crossbred calves	guar gum residue, saponin, trypsin inhibitors, haemagglutinins, hydrocyanic acid and polyphenols	<ul style="list-style-type: none"> <li>• Fungal treatment</li> <li>• Formaldehyde (1–1.5 g/100 g CP)</li> </ul>
Palm kernel cake	20% of dietary DM of goat 20–30% of concentrate mix. in goat	–	–

most effective in removing the bioactive principles of the cake for improved palatability, but there was loss of 22% dry matter (Aruwayo and Maigandi, 2013). But such loss of dry matter could be minimized by soaking in alkali solution (NaOH, 2% w/w) at 20% w/v or by ensiling with 2.5% urea (w/w) for 5–6 days rather than water washing (Nagalakshmi *et al.* 1999). Biological treatment of NSC with *A. Niger* was ineffective and the resulting product contained 7.95% phytate and 1.3% tannin (Mubarak *et al.* 2012).

*Castor oil cake:* Though castor cake is rich in CP, its use is very limited as livestock feed due to the presence of toxic factors like ricin, ricinine and allergen among which ricin is most detrimental to the animals (Bozza *et al.* 2015).

Castor seed cake detoxified by lime treatment followed by extrusion cooked could be included at 10% in ration with no adverse effect on feed conversion efficiency, intake of nutrients and milk yield of lactating Mehsana buffaloes (Bhagwat *et al.* 2012). Inclusion of up to 5% detoxified castor bean meal in the diet did not show any adverse effect on nutritive values in lactating dairy cow and sheep (Bris and Algeo, 1970; Purushotham *et al.* 1985). In order to detoxify the cake a number of physical and chemical methods were employed. Physical treatments were soaking, steaming, boiling, autoclaving and heating at different time intervals and chemical treatments were treatment with ammonia, formaldehyde, lime, sodium chloride, tannic acid and sodium hydroxide (Anandan *et al.* 2005). Anandan *et*

*al.* (2005b) observed increased IVDMD of castor cake by heating at 100°C for 30 min. Autoclaving (15 psi. 60 min), lime treatment (40 g/kg) and micro processed calcium oxide at concentration of 60 g/kg completely destroyed the ricin whereas soaking for 6 h decreased ricin upto 85% (Ananadan *et al.* 2005). Soaking over-night in 0.5% Ca(OH)<sub>2</sub> solution was very effective whereas autoclaving and soaking in 0.5% NaHCO<sub>3</sub> solution showed non-detectable levels of ricin (Oliveira *et al.* 2006). Another novel method of detoxification was wet mixing of castor seed meal with sal seed meal so that the toxic constituents of castor seed meal were neutralized by tannins present in the sal seed meal (Gandhi *et al.* 1994). Lime-treated castor meal successfully replaced soya bean meal in terms of dietary nutrients intake and the average daily gain of beef cattle (Diniz *et al.* 2010).

*Karanj cake:* Karanj cake is bitter in taste and toxic in nature due to the presence of flavonoid (karanjin), tannin and trypsin inhibitor. Kumar *et al.* (2011) reported presence of karanjin (0.57 to 1.75%), pongamol (0.25–1.27%) and trypsin inhibitor activity (790–1278 µg/g) as anti-nutritional factors in KSM. Panda *et al.* (2006) reported karanjin, tannin and trypsin inhibitor levels in solvent (SKC) and expeller pressed karanj cake (EKC) as 0.132, 3.766 and 6.550 and 0.324, 3.172 and 8.513%, respectively. Thus solvent extraction would make Karanj cake more acceptable by the animals. The removal of karanjin, tannin and trypsin inhibitor reduced adverse effects of the feed on the health of the animal. Pressure cooking at cake to water ratio of 1:0.5 was effective in reducing karanjin content whereas, treatment with alkali (1.5% (w/w NaOH or 3% w/w Ca (OH)<sub>2</sub>) was very effective in reducing the tannin (79%) and karanjin content of the cake (Panda *et al.* 2006). Gradual incorporation of deoiled karanj cake at 24 to 30% in the concentrate mixture of growing calves (Konwar *et al.* 1987) and kids (Srivastava *et al.* 1990) had no adverse effects on their performance. According to Prabhu *et al.* (2002) solvent extraction was the ultimate effective method for detoxification of karanj cake (99.99% reduction in karanjin). Soren *et al.* (2007) reported that the treatment with chemicals like lime (1% and 2.5%), sodium hydroxide (2.5%) and hydroxy sodium calcium alumino silicate (HSCAS) (0.1%) were helpful for reasonable level of incorporation of karanj cake in the livestock ration without toxic effect. TMR containing detoxified karanj cake at 5.85% when fed to crossbred cows for 90 days did not show any adverse effect on milk yield, milk fat, SNF, milk protein, total solids, density and milk production efficiency compared to TMR with Soybean meal as protein source (Raj *et al.* 2016).

*Rubber seed cake:* Treating RSC with mushroom mycelium for 96 h at room temperature reduced 81% of total cyanogens content with increased protein content of the cake (P<0.01) from 29.36% to 39.27% (Ukpebor *et al.* 2007). Storage at room temperature for a minimum period of two months was effective in reducing the hydrogen cyanide (HCN) content of rubber seeds (Narahari and

Kothandaraman, 1983).

*Mahua cake:* The cake has a bitter taste and pungent smell, which is attributed to the saponin (mowrin) present in it. Mahua oil contains 6–8% saponin (Mulky, 1976). Mowrin was found not to affect the utilization of nutrients, as it appears to be broken down in the rumen. It's degradation in the rumen of crossbred calves and excretion of degradation products in the faeces without any traces of mowrin or its degradation products in the blood sample was reported (Joshi *et al.* 1989). They recorded that mowrin could be consumed at a high a level (94 g/animal/d). Both hydrolysable and condensed tannins are present in MSC. The treatment of the MSC with NaOH (1 g NaOH/kg MSC) rendered condensed tannins soluble in water (Joshi *et al.* 1987). Overnight soaking in 1% NaOH and then water refluxing also lead to heavy loss of DM (70%) which carried about 55% of CP and whole of the NFE of the original MSC. Alkali treatment of MSC might help in releasing its nutrients for digestion in the digestive tract of animals which may otherwise be not available due to physical and chemical bondages with tannins present in MSC. Joshi *et al.* (1990) found an increase in digestibility of protein, utilization of absorbed-N and TDN intake on feeding MSC soaked in NaOH at 5% levels (W/W) for 24 h. Chahal and Sharma, (1992) found that, extracted sapogenins and sapogenols from mahua seed cake could be degraded by microbial incubation to an extent of 12.23 to 46.23% and 23.8 to 35.06%, respectively. Jain *et al.* (1995) revealed almost similar effect of treated (ferrous sulphate and formaldehyde treatment) and untreated deoiled MSC on growth rate, fleece production, nutrient utilization, however degenerative changes in the liver, kidney and testes found in untreated group, which were less pronounced in ferrous sulphate treated-DMSC and almost absent in formaldehyde treated deoiled MSC group. Ration containing MSC detoxified with 1% NH<sub>4</sub>OH resulted in increased growth rate, improved feed utilization and lesser feed cost/kg live weight gain compared to undetoxified MSC (Chahal and Sharma, 1992).

*Guar meal:* It has anti nutritional factors like guar gum residue accounting for 12% of the meal, (Lee *et al.* 2009), saponin, trypsin inhibitors, hemagglutinins, hydrocyanic acid and polyphenols (Gutierrez *et al.* 2007). The anti-trypsin activity of guar meal is lesser as compared to heat-treated as well as commercially processed soybean meal (Lee *et al.* 2004). Chemical and biological treatments have been tried for its successful inclusion in livestock ration. Protein of guar meal can effectively be protected by formaldehyde (1.5 g/100 g CP) treatment (Yadav *et al.* 2000) which was used for buffalo males. A significant decrease in tannin and gum content (75 and 50%, respectively) was achieved by fermentation of guar meal with 2 non-toxic fungi, viz. *Aspergillus niger* and *Fusarium* sp. (Nagra *et al.* 1994).

#### Conclusion

Use of non-conventional cakes and meals in ruminant ration is either restricted or limited due to presence of anti-

metabolites, viz. tannin in sal seed meal, azadirachtin, nimbin and salanin in neem seed cake, ricin, ricinine and allergen in castor cake, karanjin, tannin and trypsin inhibitor in karanj cake, cyanogens in rubber seed cake, mowrin in mahua cake etc. Various processing techniques have been tried to alleviate the toxic principles. Among various methods chemical treatment was effective in reducing toxic principles from sal seed meal, neem seed cake, castor oil cake and karanj cake. Biological treatment with fungal culture was successful for the safe inclusion of guar meal and rubber seed cake in ration. Judicious selection of detoxification techniques for removal of toxic principles from non-conventional meals and cakes might pave way for their efficient inclusion in ruminant ration and solve the problem of feed scarcity in farm animals to a considerable extent.

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