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Melia dubia Cav. drupe pulp: a new alternate livestock feed resource

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Abstract
Proximate principles, mineral matter and total phenols analysis in *Melia dubia* Cav. drupe pulp was carried out in nine populations in southern Gujarat, India. Drupe morpho-metric and biomass attributes, proximate principles, mineral matter and total phenols differed significantly among the studied populations. Average drupe length and width was found 25.60 and 20.92 mm, respectively. Whereas, average drupe fresh weight, pulp fresh weight, pulp dry weight, stone weight was 678.93, 476.45, 166.10 and 202.48 g/100 drupes, respectively and pulp, dry matter and moisture contents were 70.33,35.28 and 64.72%, respectively. Similarly, an average crude fibre, crude protein, ether extract, total ash and nitrogen free extract content of 9.97, 6.07, 2.41, 7.10 and 74.46%, respectively was found in drupe pulp of different populations. Percentage of calcium, magnesium and potassium differed significantly, whereas no significant difference was recorded in phosphorous percentage among the provenances. Overall average Ca, Mg, P and K content of 0.50, 0.16, 0.14 and 2.01%, respectively was recorded in 9 provenances. An average 0.48% total phenols were recorded which were within the permissible limit set aside for any fodder and feed resources. *M. dubia* pulp could be categorized as good feed resource with low in fibre, but rich in energy and minerals. All proximate parameters, mineral content and total phenols were in level comparable to or better than most widely browse grass, tree and shrub species, hence *M. dubia* drupe pulp could be utilized as new alternate feed source for livestock.

Keywords: Drupe, *Melia dubia,* Minerals, Phenols, Proximate principles, Pulp

Abbreviations: ALT.: Altitude; **ASL**: Above sea level; **Ca**: Calcium; **CF**: Crude fibre; **CP**: Crude protein; **CRD**: Complete randomized design; **DM**: Dry matter; **EE**: Ether extract; **K**: Potassium; **LAT**.: Latitude; **LONG**.: Longitude; **MC**: Moisture content; **Mg**: Magnesium; **NFE**: Nitrogen free extract; **P**: Phosphorus; **TA**: Total ash

Introduction

India will be facing an estimated shortage of 728 million tonnes of green fodder and 157 million tonnes of dry fodder by 2020. Thus a shortage of quality feed and fodder resources are major constraint in livestock production in the developing countries like India (Anonymous, 2012). Accordingly large number of tree species have been evaluated as leaf fodders or quality pod feeds and advocated to incorporate in the rations of livestock (Shukla and Kumar, 2007; Navale *et al*., 2017; Thakur *et al*., 2005; 2015a,b; Chauhan *et al*., 2019; Singh *et al*., 2019). Apart from tree leaves and twigs, pods and fruits are also eaten up by livestock and wild animals in the forests. However, too little research has been done on tree fruit pulps for their nutritional status and potentials as feed resources. Additionally, the use of alternative feed resources, which are adaptive to long dry season, is important for livestock production in arid region of the country. Agro-industrial by-products and/or unusual feeds may be economically advantageous. These include industrial by-products, agro-by-products, horticulture and vegetable wastes, tree pods and tree fruit pulps, weeds and other non-conventional feed resources (Andrade-Montemayor *et al*., 2011; Anonymous, 2012). The interest in seeking out alternative/additional food and feed ingredients is of overriding importance mainly because of the global demand for grains, which has exceeded the production and rigid competition between man and the livestock industry for existing food and feed materials. A challenge is, therefore, to introduce and promote alternative feed resources that have high nutritive value. Wild under-utilized plant resources must, therefore, be given more attention to bridge the gap between availability and demand of feed resources (McCalla, 2009).

There is large list of lesser-known and under-utilized tree species that have remarkable potentials as livestock feed. *Melia dubia* Cav. is one such species, drupes of which may be utilized as top feed resource, usually being left as waste in forest nurseries after extraction of stone for seedling production. The species is indigenous to

Western Ghats region in India, and is common in moist deciduous forests of the Indian states like Kerala, Tamil Nadu, Karnataka and in some parts of Gujarat. Globally, it is found in Bangladesh, Myanmar, Thailand, Mexico, Sri Lanka, Malaysia, Java, China, America, Philippines and Australia (Thakur *et al.,* 2018; Chauhan *et al*., 2018). It is a multipurpose tree, commonly known as Malabar neem or Burma neem. It is valued for its quality timber used for furniture, agricultural implements and house construction, as alternative pulp wood species, fuel wood and leaf used as a fodder (Parthiban *et al.,* 2009; Jilariya *et al*., 2017). *M. dubia* is being planted under industrial agroforestry models and is an amenable agroforestry (Mohanty *et al*., 2017; Jilariya *et al*., 2017) without any deleterious effect on under-storey crops (Thakur *et al*., 2017a,b; Kumar *et al*., 2017; Parmar *et al*., 2019). It has been observed that dear, goat and cattle rapaciously browse the fallen drupes of *M. dubia*. Fruits are available at time when all other green forage is almost absent in the deciduous forests of northern Western Ghats in Gujarat, India. Keeping in view the above, the present study was conducted to estimate proximate principle, mineral matter and total phenols in different populations of Malabar neem in Gujarat to explore the pulp as alternate feed resource from this industrially important species.

Materials and Methods

***Provenance selection and sample collection*:** This study was carried out in College of Forestry, Navsari Agricultural University, Gujarat, India during 2016-17. Samples were collected from 9 populations of *Melia dubia* distributed in northern Western Ghats of Gujarat, India. Nine provenances/populations were namely Chinchinagawtha (20° 47' 18" N, 73° 33' 40" E ; 259 m asl), Sakalpatal (20° 42' 05" N, 73° 34' 27" E ; 237 m asl), Waghai (20o 45' 22" N, 73o 29' 53" E ; 136 m asl), Dharampur (20° 26' 07" N, 73° 08" 973 E; 63 m asl), Kaprada (20° 18' 71" N, 73° 19' 36" E; 467 m asl), Nanaponda (20° 22' 49" N, 73° 09' 80" E, 129 m asl), Ingawadi (21° 42' 27" N, 73° 48' 13" E; 340 m asl), Sagai (21° 40' 54" N, 73° 47' 79" E; 437 m asl) and Devmogra (21° 36' 39" N, 73° 44' 84" E; 394 m asl). From each population, three trees of *M. dubia* were marked and drupes were collected in bulk during February to March, 2017 from all the identified population. Drupes were brought to laboratory and were washed and cleaned. Three replications (100 drupes/ replication) were drawn from each provenance to record morph-metric and biomass attributes of drupes. Manually depulped materials were used for estimation of proximate principles, mineral matter, and total phenols.

Morphometric and biomass attributes of drupes: Morphometric attributes such as drupe length (from base to tip of drupe) and drupe width (diameter at middle of drupe) were recorded. Drupe biomass attributes were also recorded such as fresh weight of drupe (g/100 drupes), fresh weight of drupe pulp (g/100 drupes), stone weight (g/100 stones), dry weight of drupe pulp (g/100), moisture content and dry matter.

Nutritional quality attributes: The proximate principles *viz*., crude fibre, crude protein, ether extract, total ash and nitrogen free extract as well as mineral constituents *viz*., calcium (Ca), phosphorus (P), magnesium (Mg) and potassium (K) were estimated from drupe pulp of *Melia dubia* collected from different population by standard procedures given by AOAC (2016). Total phenols content of drupe pulp of *Melia dubia* from different population was estimated following standard methods of biochemical analysis (Thimmaiah, 1999).

Statistical analysis: Data pertaining to proximate, mineral matter and total phenols were analyzed as per standard statistical procedure using Complete Randomized Design (CRD) following Snedecor and Cochran (1980). The means in different treatments were tested for statistical significance using Duncan's multiple range tests with significance difference of $P<0.05$.

Results and Discussion

Drupe morpho-metric and biomass attributes: There was a significant variation ($P<0.05$) among nine populations of *M. dubia* for morpho-metric traits such as drupe length and width as well as biomass attributes such as drupe fresh weight, fresh weight of pulp, dry weight of pulp, stone weight, pulp content, dry matter content and moisture percentage (Table 1). Statistically, Devmogara provenance excelled in drupe length (26.86 mm), whereas drupe width (22.84 mm), drupe fresh weight (863.60 g/100 drupes) and pulp fresh weight (561.40 g/100 drupes) were significantly higher in drupes from Kaprada provenance. Stone weight (229.50 g/100 stones) and moisture contents (70.56%) were higher in drupes collected from Ingawadi provenance. Drupes collected from Sakalpatal provenance had higher dry weight of pulp (191.30 g/100 drupes) however; maximum dry matter content (41.94%) was recorded from drupes of Waghai provenance. Interestingly, pulp content was found maximum in Chinchinagawtha provenance (73.09%).

Table 1. Variation in morpho-metric and biomass attributes of *M. dubia* drupe among different populations in Gujarat

Populations	Drupe length (mm)	Drupe width (mm)	Drupe fresh weight (g)	Pulp fresh weight (g)	Pulp dry weight (g)	Stone weight (g)	Pulp (%)	Dry matter (%)	Moisture (%)
Chinchinagawtha	26.36^{a}	20.44^{b}	682.80^{bc}	498.95^{ab}	165.15^{bc}	183.85^{c}	73.09 (58.73)^{a}	33.12 (35.11)^{bcd}	66.88 (54.85)^{abc}
Sakalpatal	25.36^{ab}	21.54^{ab}	678.00^{bc}	493.35^{ab}	191.30^{a}	184.65^{c}	72.77 (58.52)^{ab}	38.78 (38.50)^{abc}	61.22 (51.46)^{cd}
Waghai	23.63^{b}	20.29^{b}	615.40^{bc}	431.65^{b}	180.45^{ab}	183.75^{c}	70.33 (56.98)^{c}	41.94 (40.34)^{a}	58.06 (49.62)^{bd}
Dharampur	26.60^{a}	20.88^{b}	700.25^{b}	495.80^{ab}	161.75^{c}	204.45^{bc}	70.80 (57.27)^{bc}	32.68 (34.85)^{cd}	67.32 (55.12)^{ab}
Kaprada	26.59^{a}	22.84^{a}	863.60^{a}	561.40^{a}	166.95^{bc}	302.20^{a}	65.00 (53.71)^{d}	29.74 (33.03)^{d}	70.26 (56.93)^{a}
Nanaponda	24.51^{b}	20.80^{b}	661.85^{bc}	483.85^{ab}	180.15^{ab}	178.00^{c}	72.77 (58.53)^{ab}	39.07 (38.60)^{ab}	60.93 (51.36)^{cd}
Ingawadi	26.78^{a}	21.03^{b}	692.35^{bc}	462.85^{b}	135.65^{d}	229.50^{b}	66.80 (54.80)^{d}	29.44 (32.84)^{d}	70.56 (57.12)^{a}
Sagai	23.72^{b}	20.50^{b}	587.00^{c}	413.90^{b}	141.40^{d}	173.10^{c}	70.48 (57.07)^{c}	34.15 (35.74)^{bcd}	65.85 (54.22)^{abc}
Devmogara	26.86^{a}	19.93^{b}	629.10^{bc}	446.30^{b}	172.10^{bc}	182.80^{c}	70.94 (57.36)^{bc}	38.62 (38.40)^{abc}	61.38 (51.56)^{bcd}
Mean	**25.60**	**20.92**	**678.93**	**476.45**	**166.10**	**202.48**	**70.33**	**35.28**	**64.72**
SEm (±)	0.58	0.54	33.26	25.14	4.88	9.52	0.40	1.11	1.11

SEm =Standard error of means; Figures in parenthesis are arc-sign transformed values; Letter different in same vertical column are significantly different according to Duncan's multiple range test ($P \leq 0.05$)

Table 2. Variation in proximate composition of *M. dubia* drupe pulp among different populations in Gujarat

Population	CF (%)	CP (%)	EE (%)	Total ash (%)	NFE (%)
Chinchinagawtha	10.66 (19.05)^{a}	5.99(14.16)^{c}	2.42(8.94)^{cd}	5.22(13.21)^{e}	75.71(60.45)^{a}
Sakalpatal	10.01 (18.44)^{ab}	6.33(14.57)^{b}	2.30(8.68)^{cde}	5.68(13.79)^{de}	75.67(60.43)^{a}
Waghai	10.00 (18.42)^{ab}	6.49(14.75)^{ab}	1.76(7.62)^{e}	6.31(14.53)^{cd}	75.44(60.27)^{a}
Dharampur	10.33 (18.74)^{ab}	5.97(14.13)^{c}	3.10(10.08)^{ab}	6.73(15.03)^{c}	73.88(59.24)^{bc}
Kaprada	10.33 (18.75)^{ab}	6.78(15.09)^{a}	2.13(8.38)^{de}	9.49(17.93)^{a}	71.26(57.56)^{d}
Nanaponda	8.85 (17.28)^{c}	6.65(14.93)^{a}	1.90(7.93)^{de}	7.64(16.04)^{b}	74.96(59.96)^{ab}
Ingawadi	9.93 (18.36)^{ab}	5.38(13.41)^{de}	2.78 (9.59)^{bc}	7.85(16.26)^{b}	74.06(59.36)^{bc}
Sagai	10.02 (18.45)^{ab}	5.36(13.38)^{e}	3.43(10.66)^{a}	8.34(16.78)^{d}	72.85(58.57)^{c}
Devmogara	9.61 (18.05)^{bc}	5.66(13.76)^{d}	1.86(7.83)^{de}	6.60(14.85)^{c}	76.28(60.83)^{a}
Mean	**9.97**	**6.07**	**2.41**	**7.10**	**74.46**
SEm (±)	0.29	0.09	0.19	0.27	0.42

SEm =Standard error of means; Figures in parenthesis are arc-sign transformed values; Letter different in same vertical column are significantly different according to Duncan's multiple range test ($P \leq 0.05$).

Drupe morpho-metric and biomass traits variation between provenances in the present study was probably ascribed to the edapho-climatic and genetic variation in individuals of different provenances. Such variations in fruit morphometric and its biomass traits were reported earlier also in fruit size, biomass, pulp content of *Miliusa tomentosa* (Bhagora, 2017). Average moisture content of *M. dubia* drupes was 64.72% and it was even as high as 70.56%. The presence of high moisture content could be beneficial to cattle and small ruminants during dry season (Andrade-Montemayor *et al*., 2011).

Proximate principles in drupe pulp: All the proximate principle components showed significant variation ($P< 0.05$) for crude fibre, crude protein, ether extract, total ash and nitrogen free extract among all the nine studied population of *M. dubia* in northern part of Western Ghats, Gujarat (Table 2). Crude fiber varied from 8.85

(Nanaponda) to 10.66% (Chinchinagawtha) with mean value of 9.97%, whereas crude protein ranged between 5.36 (Sagai) and 6.78% (Kaprada) with mean value of 6.07%. Ether extract was higher in drupe pulp of Sagai (3.43%) population with overall mean of 2.41%. Kaprada population recorded higher total ash content of 9.49% and overall mean of 7.10%. In case of nitrogen free extract, Devmogra population recorded highest value of 76.28% and it was least in Kaprada (71.26%) with overall mean of 74.46%. Result showed good variation in different proximate principle components among nine populations and it will help in selection of genotypes for specific purpose *i.e.* if pulp is to be used with objective to offer fat rich feed then Saghai and Dharampur population can be exploited as these sources had more ether extract.

Concentrates having crude fibre and crude protein less than 18% are suggested as good and considered as energy rich feed resource (Anonymous, 2012). Present study showed that values of both crude fibre and crude protein of *M. dubia* drupe pulp fall within the prescribed limit. Similar range of crude fiber and crude protein in pod/fruit/leaves were recorded in different forest species (Sirohi *et al*., 2017; Gaikwad *et al*., 2017). Therefore, drupe pulp of *M. dubia* could be considered as energy source with low fibre and protein contents. Ether extract recorded from drupe pulp of *M. dubia* (1.76 to 3.43%) from different populations was within the range reported earlier in pods and leaves of many tropical and sub-tropical leguminous and non-leguminous browse species **(**Ganai *et al*., 2010; Khan *et al*., 2011; Gupta *et al*., 2016).

The high amount of total ash suggested a high-value mineral composition comprising potassium, calcium and iron as the main elements (Gaikwad *et al*., 2017). Pods of many *Acacia* spp. were found to contain total ash in the range of 6.30 to 8.50% (Gebeyew *et al*., 2015; Sirohi *et al*., 2017); in fact, values of total ash (5.22 to 9.49% with mean of 7.10%) recorded in *M. dubia* drupe pulp also falls within the range reported in different browsed fodder species (Khan *et al*., 2011; Gupta *et al*., 2016). It was noted that nitrogen free extract in the wastes of *Citrus* spp. ranged from 65 to 75%, whereas in jackfruit, it was 65.30%. Feed sources with such range in nitrogen free extract are considered as energy rich resources (Anonymous, 2012). In the present study, drupe pulp of *M. dubia* also showed similar range of nitrogen free extract.

Minerals in drupe pulp: Study revealed that percentage of calcium, magnesium and potassium differed significantly, whereas no significant difference was recorded in phosphorous percentage among the provenances (Table 3). Maximum Ca (0.53%) was recorded in drupe pulp of Sagai and Kaprada provenances and it was minimum (0.45%) in pulp of Devmogra provenance. Highest Mg content (0.24%) was found in pulp from Sakalpatal and it was minimum (0.10%) in drupes from Chinchinagawtha provenance. Potassium content was found higher (2.17%) in drupes from Chinchinagawtha and it was minimum (1.85%) in drupes from Saghai provenance. Although, there was no statistically significant difference in P percentage among provenances, nevertheless, it ranged from 0.12 (Chinchinagawtha) to 0.16% (Sakalpatal) in drupe pulp of *M. dubia* among the nine provenances (Table 3). Overall average Ca, Mg, P and K content of 0.50, 0.16, 0.14 and 2.01% was recorded in provenances across southern Gujarat.

Table 3. Variation in mineral composition and total phenols in *M. dubia* drupe pulp among different populations in Gujarat

Population	Ca (%)	Mg (%)	P (%)	K (%)	Total phenols (%)
Chinchinagawtha	0.53 (4.16)^{ab}	0.10 (1.84)^{e}	0.12 (1.98)	2.17 (8.47)^{ab}	0.51 (4.09)^{ab}
Sakalpatal	0.49 (4.03)^{c}	0.24 (2.82)^{a}	0.16 (2.27)	1.93 (7.98)^{bc}	0.54 (4.21)^{a}
Waghai	0.51 (4.11)^{b}	0.20 (2.58)^{b}	0.14 (2.17)	1.89 (7.91)^{c}	0.58 (4.38)^{a}
Dharampur	0.48 (3.97)^{cd}	0.13 (2.09)^{d}	0.13 (2.09)	1.92 (7.96)^{c}	0.43 (3.77)^{bc}
Kaprada	0.53 (4.19)^{a}	0.19 (2.47)^{b}	0.15 (2.22)	2.02 (8.17)^{bc}	0.50 (4.04)^{ab}
Nanaponda	0.53 (4.16)^{ab}	0.15 (2.19)^{cd}	0.15 (2.16)	2.31 (8.74)^{a}	0.34 (3.34)^{c}
Ingawadi	0.47 (3.91)^{de}	0.16 (2.29)^{c}	0.15 (2.16)	1.98 (8.07)^{bc}	0.54 (4.21)^{a}
Sagai	0.53 (4.19)^{a}	0.14 (2.17)^{cd}	0.14 (2.16)	1.85 (7.81)^{c}	0.51 (4.10)^{ab}
Devmogara	0.45 (3.86)^{e}	0.14 (2.17)^{cd}	0.13 (2.06)	2.06 (8.24)^{bc}	0.51 (4.09)^{ab}
Mean	0.50	0.16	0.14	2.01	0.50
SEm (±)	0.01	0.01	0.08	0.07	0.13

SEm =Standard error of means; Figures in parenthesis are arc-sign transformed values; Letter different in same vertical column are significantly different according to Duncan's multiple range test ($P \leq 0.05$).

It is important to note that the content of Ca and Mg found in *M. dubia* fruit pulp was adequate, P was at par with the critical level and K content was quite higher than the minimum standard as per nutrient requirement of dairy cattle, laid out by National Research Council, Washington, DC (Anonymous, 2001). Calcium and Mg content in *M. dubia* drupe pulp observed in present study was in proximity with that reported in pods and leaves of many browse species (Abdalla *et al*., 2014; Lengarite *et al*., 2014). Even the commonly adopted grasses in arid region of India, contained Ca similar to that found in *M. dubia* pulp. Phosphorous in forages like *P. typhoideum, Cencherus ciliaris, C. setigerus* and *Lasiurus sindicus* was reported in the range of 0.19 to 0.25%, the level which was found in *M. dubia* pulp. Average P contents in pods and leaves of many tropical and temperate fodder species (Ansari *et al*., 2012; Gaikwad *et al*., 2017; Navale *et al*., 2017) were within the range as observed in *M. dubia* pulp in the present investigation. Mg and K in pigment extracted annatto seed meal, advocated as goat feed (Kumar, 2007), was also in proximity with the level found in *M. dubia* fruit pulp whereas Ca levels was lower compared to *M. dubia* pulp. Further, K content in forage grasses were reported in the range of 1.00 to 1.20% of DM (Kumar and Soni, 2014), hence *M. dubia* fruit pulp contained much higher K compared to forage grasses.

Total phenols in drupe pulp: Significantly maximum total phenols (0.58%) were found in drupe pulp of Waghai provenance followed by Sakalpatal provenance (0.54%) and it was minimum (0.34%) in drupe pulp from Nanaponda provenance (Table 3). Overall, an average of 0.48% total phenols was recorded in provenances of southern Gujarat. Total phenols in important fodder and forage species ranging from 0.15 to 0.48 mg/g in leaves and from 0.11 to 0.32 mg/g in pods were considered non-toxic (Caramori *et al.,* 2004). Thus total phenol content in *M. dubia* drupe pulp indicated that it contained phenols at level comparable to most of the forage grasses and fodder tree species and it was within permissible limits. Hence, the level of total phenols found in *M. dubia* drupe pulp might be advantageous for cattle and small ruminants.

Conclusion

The study revealed that *M. dubia* pulp contained proximate principles in range which could be treated as good feed source with low in fibre, and rich in energy and minerals. The content of Ca and Mg found in *M. dubia* fruit pulp was adequate, P was at par with the critical level and K content was quite higher than the minimum requirement. An average total phenol was within the permissible limit set aside for any fodder and feed resources. Values on proximate parameters, mineral contents and total phenols were in level comparable to or better than most widely browse grass, tree and shrub species, hence *M. dubia* drupe pulp could be exploited as new alternate feed resource for livestock.

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