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Quantitative and Qualitative Analysis of Hair-fibre Attributes in Four Indian Dromedary Camel (*Camelus dromedarius*) Breeds

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ABSTRACT

Background: The livestock domestication has advanced with industrialization, civilization and technical innovations. Among all products and services, camel wool stands out for its distinct qualities and comparable with animal fibres *viz*. cashmere, alpaca, sheep and angora wool.

Methods: The present study analyzes the quantitative and qualitative attributes of camel fibre by considering four breeds (Bikaneri, Jasialmeri, Kachchhi and Mewari).

Result: Highest fibre weight in Bikaneri breed indicates higher genetic potential. The quality declined in older animals, due to age-specific management, nutrition, hair density and feeding strategies. The possibility of preparing blends fibre from camel hair with natural or synthetic fibres was indicated by the mean fibre diameter and medullation percentage. The correlation showed blanket and carpet qualities of camel hair. The results of this study suggest further improvement through selection in hair fibre attributes. Future research may focus on the genes associated with fibroblast growth.

Key words: Correlation coefficient, Dromedary camel, Fibre weight, Medullation, Synthetic fibre.

INTRODUCTION

Indian dromedary camels have long been a part of Indian heritage and culture, with the evidence of domestication dating back to as early as the Harappan period. However, the network of motorable roads even in the remotest location as well as the widespread agricultural mechanization has rendered these beasts of burden without much utility for farmers. Loss of grazing lands to development projects is a critical set back to the pastoral system in camel rearing. The Indian dromedary camels capable of thriving and yielding high-quality products such as meat, milk and fibers. The camel wool is luxury textile product, from the undercoat and crucial desert adaptation (Hasi *et al.*, 2020). Camel wool has superior over cashmere, sheep, angora and alpaca wool in terms of softness, texture, warmth, durability, sustainability, water repellent and hypoallergic properties (Iglesias Pastrana *et al.*, 2024). Hair fiber associated *KRTAP7* and *KAP6.1* genes were indicated diverse inhabitation (Bharathesree *et al.*, 2019; Yadav *et al.*, 2024).

Camel hair, a specialty hair fiber, possess two distinct types of hair: an outer protective coat layer of coarse guard hair and a fine insulating undercoat known as down. The fibers are collected by shearing or pulling or gathering the fallen clumps during molting in late spring or early summer (Franck 2001). Notable variations in camel fibers have been observed among different flocks and individual animals along with the same animal of different areas. Efforts are underway to evolve various chemical treatments aimed at boosting the production of high-quality camel hair products. The eco-friendly nature of camel wool enables it to be suitable for stitching the durable, sustainable and ethical fashion clothes (Agamy *et al.*, 2024; Xiao *et al.*, 2016). Limited studies have been carried out to evaluate the quality parameters of camel hairs globally. Therefore, the present study was conducted to explore the qualitative and quantitative characteristics of Indian Dromedary camel fibers based on the gender, breed, coat colour and different

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age groups to strategize the specific market demands for textiles, rugs, coats, blanket and other products.

MATERIALS AND METHODS

Source of information

Data collected from ICAR-NRCC, Bikaner spanning six consecutive years (2018-2023), from four breeds *viz.* Bikaneri (520), Jaisalmeri (373), Kachchhi (419) and Mewari (402) making a total of 1714 Indian Dromedary camels (*Camelus dromedarius*).

Hair-fibre attributes

Annual clipping weights for quantitative analysis with fibre diameter and medullation (%) for qualitative analysis. The hair-fibre showed varying distribution, density (higher at hump), colour and quality based on animal's body (Fig 1). Weight was measured using digital weighing balance and kept in a polythene bag after proper skirting (removal of dust and other vegetable matters). The qualitative analysis was done at TMTC division of ICAR-CSWRI, Avikanagar.

Descriptive statistics estimated from the standardized and classified data by R software v.4.2.0 (R core team, 2022). The least square means and effect of various factors were estimated by General Linear model (SPSS v.22, 2013).

Table 1: Pedigree information.

Breed	Dam	Sire	*Purchased animals
Bikaneri (142)	69	22	3
Jaisalmeri (93)	45	12	5
Kachchhi (108)	49	15	15
Mewari (106)	43	8	24

* Pedigree information unavailable.

Statistical model:

$$Y_{ijklmno} = \mu + C_i + B_j + S_k + A_l + S_{hm} + Y_n + \text{Interaction effect} + e_{ijklmno}$$

$Y_{ijklmno}$ = Observation of oth animal.

μ = Overall mean.

C_i, B_j, S_k, A_l, S_{hm} and Y_n = Effect of ith coat colour (i=1,2,3,4, 5,6,7). jth breed (j=1,2, 3, 4), kth sex (k=1,2), lth age (l=1-5 for wool weight; l=1-4 for wool quality), mth shearing (m=1,2,3,4) and nth Year (n=1-6 for wool weight; n=1,2 for wool quality) respectively; YB, YC, YS, YA and YSh-interaction of year with breed, coat colour, sex, age and shearing, respectively;

$e_{ijklmno}$ = Random error, N (0, $\sigma^2 e$).

The Bayesian analysis was performed with repeatability model using BLUPF90 (Misztal *et al.*, 2002) to estimate (co) variance, heritability, repeatability and correlation with the pedigreed camels (Table 1). Data renumbered using RENUMF90, followed by estimation using GIBBS1F90 and POSTGIBBSF90. The desired distribution attained by 99,900 Gibbs samples (10,00000 rounds, 1,000 burn-in and 10 thinning interval) and visualized by trace plot and histogram.

Repeatability model

The model considered all fixed (breed, sex, coat colour, age group, year and shearing) and random (animal) effects.

$$Y = X\beta + Z\mu + Wp + e$$

Y, β, μ and p = Vector of observed traits, fixed effects, additive genetic random effects and random animal permanent environmental effects, respectively.

X, Z and W = Incidence matrix of fixed effects, additive genetic effects and permanent environmental effects, respectively.

e = Random error, N (0, $\sigma^2 e$).



Fig 1: Coat colour patterns of hair fibre in Indian dromedary camel.

RESULTS AND DISCUSSION

Descriptive statistic

Medullation hairy and hair fibre weight were least varying and most varying trait, respectively (Table 2).

Quantitative and qualitative analysis

Effect of factors were indicated on hair-fibre weight in different years of shearing and on fibre diameter and medullation% in two years (Table 3, 4, 5, 6). The overall wool weight was highest in Bikaneri breed, red black coat-coloured animals, females and 4-6 years of age. All factors were significantly affecting the overall hair-fibre quantity and fibre diameter. The significant effect of sex and shearing numbers on overall medullation hetero; for shearing numbers on overall medullation hairy and of age group on total medullation was noticed.

Table 2: Descriptive statistics.

Parameters	Mean±SE	SD	Minimum	Maximum
Hair fibre weight (kg) (1714)	0.78±0.01	0.42	0.01	3.3
Fibre diameter (μ) (125)	34.26±0.87	9.76	20.49	73.61
Medullation hetero (120)	20.75±0.93	10.22	4.00	52.00
Medullation hairy (120)	43.62±1.94	21.27	1.67	91.33
Medullation total (120)	64.44±1.77	19.34	13.33	97.00

Table 3: LSM±S.E. and effects of breeds and sex on hair fibre weight (kg).

Parameters	Bikaneri	Jaisalmeri	Kachchhi	Mewari	Mean ± S.E.	Male	Female
2018	0.97^{a}±0.08 (34)	0.86^{b}±0.08 (24)	0.79^{b}±0.08 (26)	0.80^{b}±0.08 (24)	0.86^{B}±0.06 (108)	0.93±0.11 (21)	0.79±0.05 (87)
2019	1.06^{ab}±0.06 (106)	0.87^{b}±0.07 (71)	1.02^{b}±0.07 (81)	1.04^{a}±0.07 (88)	0.99^{A} ± 0.04 (346)	1.02±.05 (137)	0.97±0.04 (209)
2020	0.82^{a}±0.04 (118)	0.73^{a}±0.06 (79)	0.77^{a}±0.05 (92)	0.73^{a}±0.06 (88)	0.76^{B}±0.03 (377)	0.75±0.04 (158)	0.77±0.03 (219)
2021	0.64^{a}±0.04 (81)	0.51^{b}±0.05 (71)	0.58^{ab}±0.05 (75)	0.55^{ab}±0.05 (68)	0.57^{C}±0.03 (295)	0.53^{b}±0.03 (123)	0.61^{a}±0.03 (172)
2022	0.76^{a}±0.03 (101)	0.69^{a}±0.04 (69)	0.69^{a}±0.04 (78)	0.76^{a}±0.04 (71)	0.73^{B}±0.02 (319)	0.75±0.03 (139)	0.70±0.03 (180)
2023	0.79^{ab}±0.05 (80)	0.70^{b}±0.06 (59)	0.71^{b}±0.06 (67)	0.89^{a}±0.06 (63)	0.77^{B}±0.03 (269)	0.76±0.04 (111)	0.78±0.04 (158)
Overall mean±S.E.	0.83±0.02	0.72±0.03	0.76±0.03	0.79±0.03	0.78±0.01(1714)	0.77±0.02	0.78±0.02

Note: LSM=Least squares mean; Values in parenthesis= Number of observations.

Table 4: LSM±S.E. and effects of various coat colour patterns.

Colour code	2018	2019	2020	2021	2022	2023	Overall mean±S.E.
1	0.74^{b}±0.11 (10)	0.91^{ab}±0.10 (37)	0.76^{a}±0.08 (40)	0.60^{a}±0.07 (32)	0.67^{b}±0.06 (32)	0.75^{a}±0.09 (27)	0.74±0.04
2	0.70^{b}±0.09 (20)	0.84^{ab}±0.07 (67)	0.73^{a}±0.06 (76)	0.60^{a}±0.05 (63)	0.74^{b}±0.04 (69)	0.76^{a}±0.06 (61)	0.74±0.04
3	0.85^{b}±0.11 (10)	0.82^{b}±0.10 (26)	0.78^{a}±0.09 (26)	0.50^{a}±0.07 (22)	0.88^{a}±0.06 (25)	0.85^{a}±0.09 (22)	0.76±0.04
4	0.68^{b} ±0.09 (17)	1.12^{ab}±0.07 (57)	0.74^{a}±0.05 (70)	0.57^{a}±0.05 (58)	0.72^{b}±0.04 (61)	0.77^{a}±0.06 (52)	0.78±0.02
5	1.37^{a}±0.16 (5)	1.11^{a}±0.15 (13)	0.78^{a}±0.11 (17)	0.56^{a}±0.11 (9)	0.71^{b}±0.09 (11)	0.67^{a}±0.15 (7)	0.83±0.05
6	0.86^{b}±0.12 (8)	1.11^{a}±0.10 (35)	0.79^{a}±0.08 (38)	0.60^{a}±0.07 (26)	0.63^{b}±0.06 (33)	0.78^{a}±0.08 (30)	0.80±0.04
7	0.78^{b}±0.07 (38)	1.05^{ab}±0.05 (111)	0.75^{a}±0.04 (110)	0.56^{a}±0.04 (85)	0.72^{b}±0.03 (88)	0.84^{a}±0.05 (70)	0.78±0.02

LSM= Least squares mean; Colour codes indicated as: 1= Black; 2= Black brown; 3= Brown; 4= Red; 5= Red black; 6= White; 7= Yellow; Values in parenthesis = Number of observations.

Table 5: LSM±S.E. and effects of different age groups.

Parameters	2 Months-2 Year	2-4 Years	4-6 Years	6-10 Years	>10 Years (10-23 Years)
2018	0.75^{a}±0.06 (29)	0.843^{a}±0.14 (6)	0.78^{a}±0.11 (12)	0.93^{a}±0.09 (29)	0.98^{a}±0.09 (32)
2019	0.67^{a}±0.06 (72)	1.00^{b}±0.06 (82)	1.20^{b}±0.07 (58)	1.05^{b}±0.07 (63)	1.06^{b}±0.07 (71)
2020	0.53^{c}±0.05 (84)	0.74^{b}±0.05 (86)	0.80^{ab}±0.06 (58)	0.92^{a}±0.05 (69)	0.82^{ab}±0.05 (80)
2021	0.66^{a}±0.04 (82)	0.53^{a}±0.06 (34)	0.57^{a}±0.05 (57)	0.55^{a}±0.05 (57)	0.54^{a}±0.05 (65)
2022	0.60^{b}±0.04 (54)	0.70^{a}±0.04 (67)	0.74^{a}±0.04 (56)	0.79^{a}±0.04 (67)	0.79^{a}±0.04 (75)
2023	0.71^{a}±0.08 (28)	0.86^{a}±0.05 (65)	0.83^{a}±0.06 (44)	0.75^{a}±0.05 (74)	0.73^{a}±0.06 (58)
Age wise overall	0.64±0.02	0.77±0.02	0.83±0.03	0.82±0.02	0.82±0.02

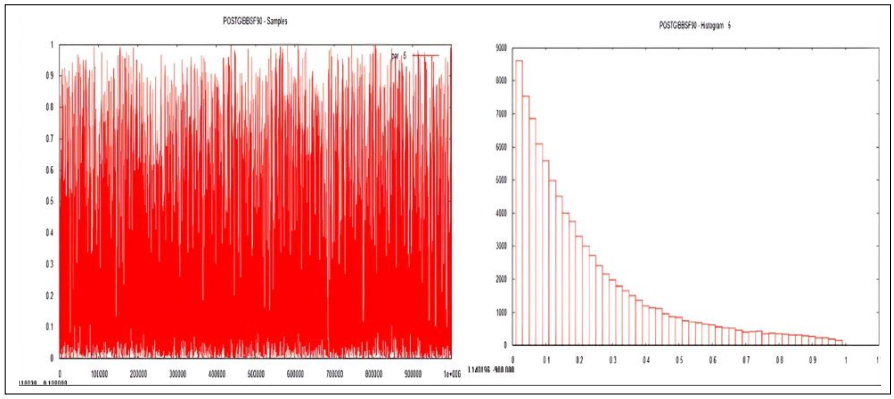


Fig 2: Trace plot and histogram for hair quantity trait in Bikaneri breed.

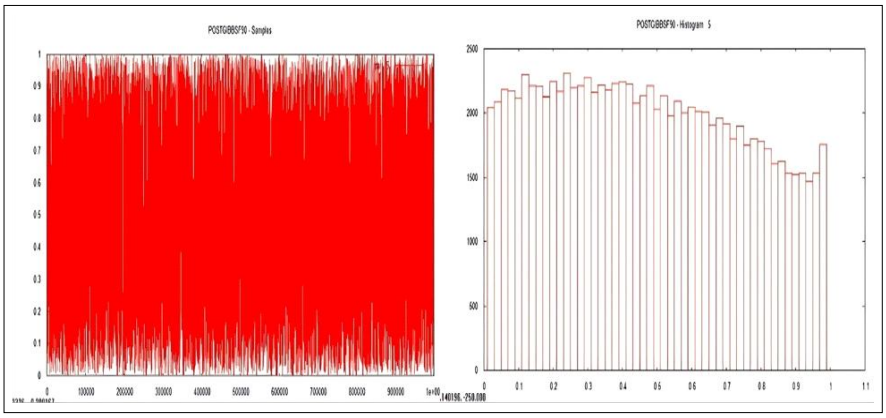


Fig 3: Trace plot and histogram for hair quantity trait in Jaisalmeri breed.

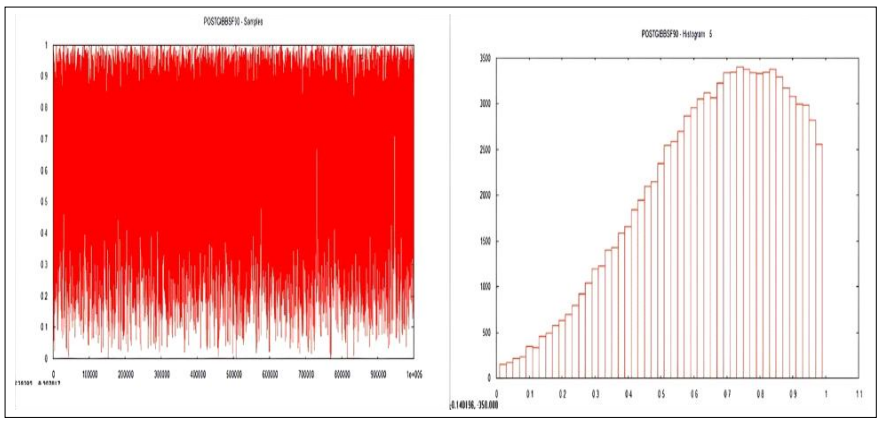


Fig 4: Trace plot and histogram for hair quantity trait in Kachchhi breed.

Table 6: LSM ± S.E. and effects of various factors on hair fibre quality.

Parameters	Fibre diameter			Medullation hetero			Medullation hairy			Medullation total		
	2020	2022	Overall mean±S.E.	2020	2022	Overall mean±S.E.	2020	2022	Overall mean±S.E.	2020	2022	Overall mean±S.E.
Mean±S.E.	34.82±1.91	33.67±2.95	35.34±1.37	16.51±1.76	28.81±3.89	20.54±1.47	46.54±4.49	28.50±5.68	43.74±2.89	63.55±4.17	57.27±7.24	63.936±3.007
	(68)	(52)	(120)	(68)	(52)	(120)	(68)	(52)	(120)	(68)	(52)	(120)
Breed												
Bikaneri	29.15^{b}±2.68	29.24±3.66	31.72^{b}±1.89	19.62±2.47	29.56±4.83	20.77±2.02	42.90^{b}±6.31	13.61^{c}±7.06	34.89^{b}±3.98	61.70^{b}±5.85	42.96^{b}±9.00	54.59^{b}±4.14
	(19)	(15)	(34)	(19)	(15)	(34)	(19)	(15)	(34)	(19)	(15)	(34)
Jaisalmeri	37.41^{a}±2.95	33.66±3.59	36.24^{a}±2.05	16.26±2.73	27.31±4.73	20.97±2.20	50.93^{a}±6.96	33.09^{b}±6.91	47.40^{a}±4.33	68.93^{a}±6.46	59.38^{ab}±8.80	68.33^{a}±4.50
	(18)	(13)	(31)	(18)	(13)	(31)	(18)	(13)	(31)	(18)	(13)	(31)
Kachchhi	40.97^{a}±3.81	32.251±4.00	37.91^{a}±2.51	11.99±3.51	29.68±5.27	18.30±2.69	51.48^{a}±8.97	23.73^{b}±7.71	46.02^{a}±5.29	63.91^{ab}±8.32	53.40^{b}±9.82	63.76^{a}±5.50
	(16)	(13)	(29)	(16)	(13)	(29)	(16)	(13)	(29)	(16)	(13)	(29)
Mewari	31.74^{a}±3.35	39.51±4.34	35.48^{a}±2.43	18.17±3.09	28.69±5.73	22.14±2.60	40.84^{ab}±7.90	43.58^{a}±8.37	46.65^{a}±5.11	59.65^{ab}±7.33	73.35^{a}±10.66	69.06^{a}±5.32
	(15)	(11)	(26)	(15)	(11)	(26)	(15)	(11)	(26)	(15)	(11)	(26)
Colour												
Black	36.17^{b}±4.15	38.02±4.82	37.32±2.93	14.53±3.83	28.57±6.35	20.60±3.14	36.76^{b}±9.78	31.23^{bc}±9.28	38.27^{b}±6.17	51.49^{b}±9.07	59.93^{ab}±11.83	58.51^{b}±6.42
	(7)	(5)	(12)	(7)	(5)	(12)	(7)	(5)	(12)	(7)	(5)	(12)
Black	31.39^{ab}±3.00	36.61±3.74	36.12±2.06	19.97±2.77	26.69±4.93	20.94±2.21	48.62^{a}±7.06	31.89^{ab}±7.20	43.32^{ab}±4.34	68.36^{a}±6.55	59.08^{ab}±9.18	64.05^{ab}±4.51
Brown	(16)	(14)	(30)	(16)	(14)	(30)	(16)	(14)	(30)	(16)	(14)	(30)
Brown	28.27±6.04		28.27±6.04	18.44±6.48		18.44±6.48	43.12^{ab}±12.73		43.12^{ab}±12.73	61.45^{ab}±13.24		61.45^{ab}±13.24
	(2)	-	(2)	(2)	-	(2)	(2)	-	(2)	(2)	-	(2)
Red	39.99^{a}±3.19	33.64±3.81	37.86±2.06	16.64±2.94	26.47±5.02	19.88±2.21	51.07^{a}±7.51	30.84^{abc}±7.34	46.25^{ab}±4.34	70.23^{a}±6.97	57.77^{ab}±9.35	67.07^{ab}±4.52
	(15)	(12)	(27)	(15)	(12)	(27)	(15)	(12)	(27)	(15)	(12)	(27)
Red black	36.10^{b}±4.07	38.27±6.64	36.15±3.47	17.19±3.76	28.07±8.76	23.28±3.72	49.61^{ab}±9.60	26.78^{c}±12.80	40.60^{b}±7.31	67.09^{ab}±8.91	54.60^{b}±16.31	63.22^{ab}±7.60
	(5)	(2)	(7)	(5)	(2)	(7)	(5)	(2)	(7)	(5)	(2)	(7)
White	38.41^{ab}±3.80	21.37±4.69	34.38±2.84	18.89±3.50	29.01±6.19	20.02±3.04	61.09^{a}±8.93	26.46^{a}±9.04	49.52^{a}±5.98	80.04^{a}±8.29	55.38^{a}±11.52	68.85^{a}±6.22
	(9)	(5)	(14)	(9)	(5)	(14)	(9)	(5)	(14)	(9)	(5)	(14)
Yellow	35.28^{ab}±2.67	34.10±3.66	37.26±1.83	14.95±2.46	34.05±4.83	20.65±1.96	53.58^{a}±6.29	23.81^{ab}±7.05	45.12^{ab}±3.85	68.02^{a}±5.84	56.87^{a}±8.98	64.41^{ab}±4.01
	(14)	(14)	(28)	(14)	(14)	(28)	(14)	(14)	(28)	(14)	(14)	(28)
Sex												
Male	36.89±2.19	33.93±3.35	36.78±1.57	17.07±2.02	24.85±4.41	18.72^{b}±1.69	45.50±5.17	27.57±6.45	42.89±3.32	63.66±4.80	52.42±8.22	61.64±3.45
	(38)	(25)	(63)	(38)	(25)	(63)	(38)	(25)	(63)	(38)	(25)	(63)

Table 6: Continue ....

Table 6: Continue ....

Female	32.74±2.27	33.40±3.00	33.90±1.61	15.95±2.10	32.77±3.96	22.37^{a}±1.73	47.58±5.36	29.44±5.79	44.59±3.40	63.43±4.97	62.12±7.38	66.24±3.53
	(30)	(27)	(57)	(30)	(27)	(57)	(30)	(27)	(57)	(30)	(27)	(57)
Age												
2 Months-1	30.98^{b}±1.33	34.24±6.17	30.21^{b}±3.96	14.75^{b}±1.16	36.36^{a}±8.14	25.41^{b}±4.24	56.35^{a}±2.63	26.32±11.89	48.04^{a}±8.33	71.72±2.32	2.40±15.15	72.35^{a}±8.67
Year	(40)	(2)	(42)	(40)	(2)	(42)	(40)	(2)	(42)	(40)	(2)	(42)
1-2 Years	-	32.67±2.67	30.28^{b}±2.77		26.61^{ab}±3.52	22.25^{a}±2.97		30.45±5.14	39.04^{b}±5.84		57.30±6.54	61.62^{b}±6.07
		(25)	(25)	-	(25)	(25)	-	(25)	(25)	-	(25)	(25)
2-4 Years	28.47^{b}±1.88	34.09±3.00	32.67^{b}±2.40	22.33^{a}±2.83	23.46^{b}±3.96	19.82^{a}±2.58	36.57^{b}±5.95	28.74±5.79	36.37^{b}±5.07	58.90±5.41	52.11±7.38	56.07^{b}±5.27
	(7)	(25)	(32)	(7)	(25)	(32)	(7)	(25)	(32)	(7)	(25)	(32)
>4 Years	48.19^{a}±2.19		48.19^{a}±3.28	14.70^{b}±1.66		14.70^{b}±3.51	51.52^{a}±5.54		51.52^{a}±6.91	65.71±7.15		65.71^{a}±7.18
	(21)	-	(21)	(21)	-	(21)	(21)	-	(21)	(21)	-	(21)
Shearing												
1st	30.98^{b}±1.33	31.70±8.13	35.75^{b}±4.42	14.75±1.16	26.82±10.72	14.67^{b}±4.73	56.35±2.63	20.55±15.67	44.56^{a}±9.30	71.72±2.32	50.09±19.96	60.13±9.67
	(40)	(1)	(41)	(40)	(1)	(41)	(40)	(1)	(41)	(40)	(1)	(41)
2nd	43.34^{a}±2.61	31.28±2.41	32.34^{a}±1.83	15.67±1.81	33.33±3.18	25.04^{a}±1.96	48.16±5.37	25.70±4.65	36.41^{b}±3.85	64.08±6.73	58.97±5.93	61.20±4.00
	(22)	(20)	(42)	(22)	(20)	(42)	(22)	(20)	(42)	(22)	(20)	(42)
3rd	34.39^{b}±4.22	33.82±3.05	34.39^{b}±2.60	20.39±2.65	29.07±4.03	22.15^{a}±2.79	51.61±9.30	34.71±5.88	47.17^{b}±5.48	72.00±5.51	63.60±7.49	69.40±5.70
	(6)	(23)	(29)	(6)	(23)	(29)	(6)	(23)	(29)	(6)	(23)	(29)
4th	-	37.87±3.92	38.87^{a}±3.77		26.02±5.17	20.31^{a}±4.04		33.05±7.55	46.82^{b}±7.94		56.41±9.62	65.02±8.26
		(8)	(8)	-	(8)	(8)	-	(8)	(8)	-	(8)	(8)

Bayesian approach using animal model

The univariate analysis indicates higher residual and permanent environmental variance for Bikaneri breed (Table 7). In trace plot iterations are on X-axis and variance on Y-axis (Fig 2, 3, 4 and 5). Negative correlation was also noticed for hair fibre attributes (Table 8).

The high genetic potential of hair yield and fibre diameter were in accordance with Bhakat *et al.* (2002), Sahani *et al.* (1996 and 1998). The superior production in male camel is under hormonal influences. The high yield in adult camel is due to larger body size, higher hair density, nutrition and management. The year wise comparison indicates different feeding and managemental practices which are beneficial for selection decision making. Average fibre diameter (28.273±6.043 µ to 48.190±3.278 µ) ranging higher than (27.22 µ-31.45 µ) reported by Yadav *et al.* (2000) and in sheep (26 µ-38 µ) by Gupta *et al.* (1989).

The normalization of estimates indicated by constant trace plot (convergence) and bell-shaped histogram. The low to higher heritability as 0.07 (Bai *et al.*, 2006), 0.10 (Zhou *et al.*, 2002), 0.16 (Jinquan *et al.*, 2001) 0.26 (Gifford *et al.*, 1990), 0.29 (Pattie and Restall, 1989), 0.33 (Rose *et al.*, 1992) and 0.71 (Bishop and Russel, 1996) were reported for Cashmere fiber. Higher additive genetic variance, heritability and repeatability in Kachchhi breed are considerable in selection decision making (Yadav *et al.*, 2022; 2023a; 2023b).

The mean fibre diameter and medullation (%) revealed blending camel hair-fibre with natural or synthetic fibres. The herbal feed additives are helpful in economic

Table 7: Posterior means (95% HPD: highest posterior density region in parenthesis) of genetic parameters for hair fibre weight (kg).

Parameter	σ^2_a	σ^2_{pe}	σ^2_e	σ^2_p	h^2±SD	r±SD
Bikaneri	0.15	0.76	0.74	1.65	0.089±0.083	0.21±0.21
	(0.000014-0.45)	(0.00033-1.50)	(0.00057-1.50)	(1.25-2.10)	(0.000007-0.26)	(0.000015-0.68)
Jaisalmeri	0.53	0.56	0.57	1.66	0.30±0.21	0.47±0.28
	(0.000081-1.44)	(0.000019-1.26)	(0.00048-1.26)	(1.09-2.32)	(0.000046-0.71)	(0.00031-0.94)
Kachchhi	0.81	0.41	0.41	1.64	0.48±0.19	0.66±0.22
	(0.089-1.58)	(0.000083-0.97)	(0.000034-0.96)	(1.12-2.19)	(0.12-0.84)	(0.25-0.99)
Mewari	0.49	0.85	0.86	2.19	0.21±0.16	0.38±0.26
	(0.000076-1.29)	(0.00074-1.80)	(0.00011-1.80)	(1.53-2.93)	(0.000013-0.52)	(0.000042-0.87)

σ^2_a - Additive genetic variance; σ^2_{pe} - Permanent environmental variance; σ^2_e - Residual variance; σ^2_p - Phenotypic variance; h^2 - Heritability; r - Repeatability; SD - Standard deviation.

Table 8: Correlation coefficient.

Parameter	Bikaneri	Jaisalmeri	Kachchhi	Mewari	Dark colour	Medium colour	Light colour
rg12 ± MCE	-0.16±0.099	-0.56±0.23	0.03±0.81	-0.086±0.06	0.30±0.05	-0.37±0.28	-0.65±0.054
rg13 ± MCE	0.009±0.03	0.03±0.03	NE	NE	0.15±0.05	0.005±0.02	0.69±0.08
rg23 ± MCE	-0.06±0.06	-0.012±0.02	NE	NE	0.50±0.20	-0.005±0.01	-0.60±0.05

Correlation between = Hair-fibre weight and fibre diameter (rg12); Hair-fibre weight and M hetero (rg13); Fibre diameter and M hetero (rg23), Dark colour - Blackish, black brown and brownish; Medium colour - Reddish and red black; light colour - Whitish and yellowish; MCE - Monte Carlo Error.

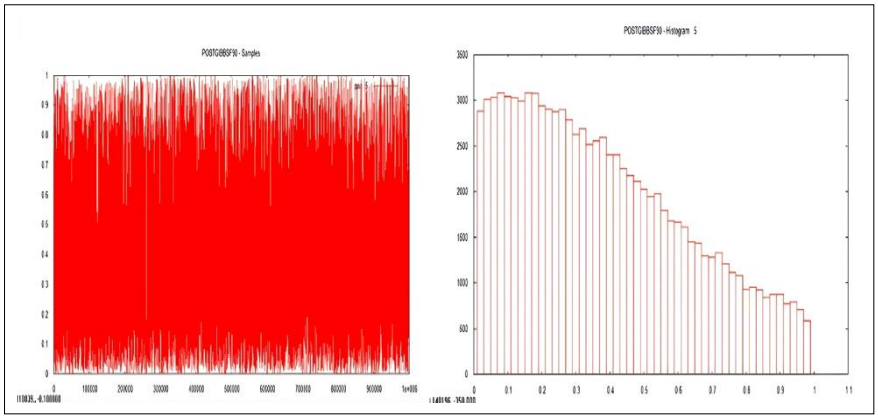


Fig 5: Trace plot and histogram for hair quantity trait in Mewari breed.

improvement of hair fibre (Mejia-Delgadillo *et al.*, 2021). The negative correlation was in accordance with blanket and carpet fibres while positive correlation was similar to yarn in Chokla and Merino wool (Gupta *et al.*, 1998). The breed wise and coat colour wise correlated response to selection can be achieved.

CONCLUSION

Our work provides the phenotypic and genetic significance of hair production traits. The studied traits have several futuristic benefits *viz*. simple and easily demonstrable from a mere distance, used to manufacture the economically sustainable and organic textile product. The variations in fibre color and quality are important to capture diverse textile market and preparation of blends camel hair fibre to produce superior fabrics. The significant effect of factors on hair fibre attributes and correlation signify further improvement by selection which can be combined with fibroblast growth associated genes in future.

Conflict of interest

There is no conflict of interest to the proposed work.

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