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Production Continuity as a Correlate of Household Milk Yield in Agro-Pastoral Cow and Camel Systems: Evidence from the 2022 Somalia Integrated Household Budget Survey

Ali Abdulle Omar

bincali17@snu.edu.so

Somali National University https://orcid.org/0009-0007-6572-5693

Nur Mohamud Ali

Somali National University

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Abstract

Cow and camel milk support household nutrition and livelihoods in Horn of Africa agro-pastoral systems. This cross-sectional secondary analysis of the 2022 Somalia Integrated Household Budget Survey examined whether the number of months in which a household produced milk during the preceding 12 months was associated with monthly yield and whether this association differed between cow and camel milk. The analysis included 681 household-product records from 652 households (344 cow-milk and 337 camel-milk records) reporting quantities in litres. Production duration and species predicted natural-log-transformed monthly yield in ordinary least-squares regression with household-clustered robust standard errors. Sensitivity analyses assessed robustness. Production duration was positively correlated with monthly yield for cow milk (Pearson's r = 0.336; Spearman's ρ = 0.298) and camel milk (Pearson's r = 0.333; Spearman's ρ = 0.306). The species × duration interaction was unsupported ($F(1, 677) = 0.365$, $p = 0.546$). Each additional production month was associated with 16.0% higher monthly yield ($\beta = 0.149$, 95% confidence interval [0.109, 0.189], $p < 0.001$). After adjustment for duration, camel milk had an estimated 16.8% higher yield than cow milk, but the difference was not statistically significant ($\beta = 0.155$, 95% confidence interval [− 0.068, 0.378], $p = 0.173$). The positive duration–yield association remained significant across all sensitivity analyses. Production duration was a more consistently supported correlate of household-level yield than species identity. Because the data were cross-sectional and household-aggregated, this association should not be interpreted as causal; longitudinal, animal-level data are needed.

Introduction

Milk from cattle and camels is an important source of food and income in agro-pastoral systems in the Horn of Africa. In dryland production systems, households often maintain mixed herds to support nutrition and livelihood resilience under seasonal and climatic stress (Mirkena et al. 2018; Rahimi et al. 2022). Smallholder dairy production can contribute to household food and nutrition security, resilience, and income (Banda et al. 2021; Hassan et al. 2026). In Somalia, milk yield is an important breeding preference among cattle keepers (Mumin et al. 2025), while camel dairy production is constrained by management and animal-health conditions as well as biological factors (Hassan et al. 2026; Nagy et al. 2022).

At the individual-animal level, lactation persistency—the ability to maintain milk yield after peak lactation—is associated with cumulative milk production (Strapáková et al. 2016; Torshizi et al. 2019). In dairy cattle, milking frequency, nutrition, and calving season can affect persistency and milk yield (Bateki et al. 2020; Kashongwe et al. 2017; Mukasafari et al. 2025). Camel lactation is often longer and variable, and milk production can be influenced by feeding, calf management, health, and herd conditions (Chamekh et al. 2020; Nagy and Juhász 2016; Nagy et al. 2022). In pastoral camel systems, milk offtake also varies among households and has been associated with management-related factors, including calf management (Kashongwe et al. 2017; Nagy et al. 2022).

The household-level measure of production duration used in this study differs conceptually from animal-level lactation persistency. It reflects the number of months in which a household reported producing a given milk type and may represent production pooled across more than one animal. Nevertheless, it may provide a practical, survey-based indicator of production continuity where individual-animal records are unavailable. Evidence remains limited on whether household-level production duration is associated with monthly milk yield across cattle and camels within the same agro-pastoral sample, and no published study has examined this association using the Livestock_byproducts module of the SIHBS 2022.

This study analysed the SIHBS 2022 Livestock_byproducts module to (i) describe production duration and average monthly milk yield among cow- and camel-milk producing households, and (ii) determine whether production duration during the preceding 12 months was associated with average monthly milk yield, and whether this association differed between cow milk and camel milk. This approach complements existing SIHBS-based research on household water access and other welfare indicators (Ahmed and Ali 2025) by extending secondary analysis of the 2022 survey to household livestock byproduct records.

Materials and methods

Study context

The Federal Republic of Somalia is located in the Horn of Africa and covers approximately 637,657 km², with a coastline of about 3,333 km, one of the longest in Africa. The country experiences a hot dryland climate, with two rainy seasons (Gu and Deyr) and two dry seasons (Hagaa and Jilaal), and livestock-keeping households commonly maintain mixed cattle and camel herds to manage seasonal feed and water variability. Agro-pastoral and pastoral households across Somalia rely on cow and camel milk both for household consumption and for income from surplus sales, making milk production continuity a practically relevant household-level outcome.

Data source and sampling design

This was a cross-sectional secondary analysis of the 2022 Somalia Integrated Household Budget Survey (SIHBS), a nationally representative household survey conducted by the Somalia National Bureau of Statistics (Somalia National Bureau of Statistics 2023). The target population comprised all households in Somalia, while the study population comprised households sampled across all Somali regions except Middle Jubba, which was excluded for security reasons, and covered urban, rural, and nomadic areas (Somalia National Bureau of Statistics 2023). The SIHBS 2022 sampling frame employed a stratified, multistage probability cluster design, in which primary and secondary sampling units were selected within strata, followed by random selection of households within the sampled clusters. Data were collected through face-to-face, computer-assisted personal interviews (CAPI). The primary respondent

was the household head and/or spouse; when neither was available, the most knowledgeable household member was selected (Somalia National Bureau of Statistics 2023).

The present study used data from the Livestock_byproducts module of the SIHBS 2022, which recorded household-level production of milk and other livestock byproducts and required data extraction, cleaning, and variable construction specific to milk-production reporting. The analytical unit was the household–product record, because the milk-production variables were reported and analysed at the household–product level rather than solely at the household level.

Study variables

Outcome variable

The outcome variable was the average monthly quantity of milk produced by the household for a given species, reported in litres. In the SIHBS 2022 Livestock_byproducts module, households reporting cow-milk or camel-milk production were asked to report the quantity produced per month, expressed in the unit used by the household (litres, kilograms, or another unit). Only records reported in litres were retained for this analysis, for the reasons given above. Because the outcome was strongly right-skewed, it was analysed on the natural-log scale in the regression models.

Independent variables

The primary exposure variable was production duration, defined as the number of months, out of the preceding 12 months, during which the household reported producing the given milk type. This variable was treated as a household-level proxy for production continuity, not as a direct measure of individual-animal lactation persistency. The second exposure variable was species/product, coded as cow milk or camel milk, with cow milk as the reference category. Household identifier was retained as a clustering variable to account for households contributing more than one product record.

Operational definition

Production continuity, as operationalised in this study, refers to the number of months within a 12-month recall period during which a household reported active milk production for a given species, irrespective of the number of lactating animals contributing to that production. This household-level definition is distinct from the animal-level concept of lactation persistency, which describes an individual animal's ability to sustain milk yield after peak lactation (Torshizi et al. 2019).

Data management and statistical analysis

Average monthly milk yield was positively skewed in both species. Raw yield departed from normality in cow milk (Shapiro–Wilk $W = 0.339$, $p < 2 \times 10^{-16}$) and camel milk ($W = 0.618$, $p < 2 \times 10^{-16}$). The natural logarithm of monthly yield was therefore used as the regression outcome; log transformation is commonly used for right-skewed outcomes and allows regression coefficients to be interpreted as approximate proportional changes on the original scale (West 2022).

An initial regression model included centred production duration, species, and their interaction term. The interaction was tested against the additive model; because it was not statistically supported, the additive model was retained as the primary specification. The primary model used ordinary least-squares regression with household-clustered robust standard errors, to account for the non-independence of records contributed by the same household (Cameron and Miller 2015; Zeileis et al. 2020).

Model diagnostics included variance inflation factors, the Shapiro–Wilk test of residuals, the Breusch–Pagan test for heteroskedasticity, and visual diagnostic plots. Sensitivity analyses comprised: (a) a household random-intercept model; (b) re-estimation after excluding 47 observations identified using the Tukey far-outlier rule, applied separately by species; (c) conventional non-clustered standard errors; and (d) Spearman rank correlations. All analyses were conducted in R and RStudio, using the sandwich, lmtest, lme4, and car packages.

Results

Socio-demographic and production characteristics of the sample

The final analytic sample comprised 681 household-product records from 652 households: 344 cow-milk records and 337 camel-milk records. Twenty-nine households (4.4%) contributed records for both cow and camel milk. Table 1 presents production duration and average monthly milk yield by species. Mean (SD) production duration was 5.88 (3.14) months for cow milk and 6.19 (3.35) months for camel milk, with similar medians of 6 months for both species. Mean (SD) monthly yield was 314.34 (862.43) L for cow milk and 284.81 (448.16) L for camel milk; median monthly yield was 80 L (IQR 30–240) for cow milk and 120 L (IQR 40–300) for camel milk. Monthly yield ranged from 2 to 9,000 L for cow milk and from 1 to 3,600 L for camel milk. The difference between means and medians indicated substantial right-skewness, particularly for cow milk; medians and interquartile ranges therefore provide the most representative descriptive summary.

Table 1
Production duration and average monthly milk yield by species

Species	n	Duration, mean (SD), months	Duration, median (IQR), months	Yield, mean (SD), L/month	Yield, median (IQR), L/month
Cow milk	344	5.88 (3.14)	6 (3–8)	314.34 (862.43)	80 (30–240)
Camel milk	337	6.19 (3.35)	6 (4–8)	284.81 (448.16)	120 (40–300)

Note. Source: Own compilation from SIHBS 2022, Livestock_byproducts module.

Distributional assessment of milk yield

After natural-log transformation, the cow-milk distribution was approximately normal (Shapiro–Wilk W = 0.992, p = .068). Camel milk retained a small, statistically detectable deviation from normality (W = 0.980, p = .000119). Visual inspection indicated substantially improved symmetry on the log scale for both species (Fig. 1), supporting the use of the log-transformed outcome in the regression models (Fig. 1). Species-specific medians, interquartile spreads, and outliers are presented in Fig. 2.

Association between production duration and monthly milk yield

Production duration was positively correlated with monthly milk yield in both groups. Pearson's correlation was 0.336 for cow milk and 0.333 for camel milk. Spearman's rank correlation was 0.298 for cow milk and 0.306 for camel milk; both Spearman correlations had $p < 0.001$. An auxiliary regression of production duration on species yielded $R^2 = 0.0022$, and a Welch two-sample test showed no statistically significant difference in production duration between species ($t = -1.219$, $df = 674.18$, $p = 0.223$; 95% CI for the mean difference [– 0.79, 0.19] months), indicating that cow- and camel-milk households reported broadly similar production durations (Fig. 3).

Multivariable regression analysis of production duration and species on monthly milk yield

Table 2 presents the additive linear regression model for natural-log-transformed average monthly milk yield. The species × duration interaction was not statistically supported ($F(1, 677) = 0.365$, $p = 0.546$), and the additive model was therefore selected as the primary specification. Each additional month of reported production duration was associated with 16.0% higher average monthly milk yield ($\beta = 0.149$, robust SE = 0.020, 95% CI [0.109, 0.189], $p < .001$; back-transformed 95% CI [11.5%, 20.8%]). Camel milk had an estimated 16.8% higher yield than cow milk after adjustment for duration, but this difference was not statistically significant ($\beta = 0.155$, robust SE = 0.114, 95% CI [– 0.068, 0.378], $p = .173$).

Table 2
Additive linear regression model for natural-log-transformed average monthly milk yield

Term	β, log scale	Robust SE	95% CI	p	Back-transformed interpretation
Intercept: cow milk at mean duration	4.454	0.082	[4.294, 4.615]	< .001	Approximately 86 L/month
Production duration, per additional month	0.149	0.020	[0.109, 0.189]	< .001	16.0% higher yield
Camel milk versus cow milk	0.155	0.114	[− 0.068, 0.378]	.173	16.8% higher yield; not statistically significant

Note. Source: Own compilation from SIHBS 2022, Livestock_byproducts module. N = 681 records from 652 households. Standard errors were clustered by household. Adjusted R^2 = .093. Cow milk was the reference category. The intercept was back-transformed as exp(4.454) and represents estimated yield for cow milk at mean-centred production duration.

Model diagnostics and sensitivity analyses

Variance inflation factors were approximately 1.002 for both production duration and species, indicating no meaningful multicollinearity. Residuals departed statistically from normality (Shapiro–Wilk W = 0.987, $p = 9.7 \times 10^{-6}$), and heteroskedasticity was detected (Breusch–Pagan $\chi^2 = 28.37$, df = 1, $p = 1.0 \times 10^{-7}$); the cluster-robust standard errors used in the primary analysis address both heteroskedasticity and within-household dependence. Diagnostic plots are shown in Fig. 4.

Table 3 summarises the four sensitivity analyses. Across all of them, the association between production duration and monthly yield remained positive and statistically significant. The estimated duration coefficient ranged from 0.086 to 0.149 on the log scale, corresponding to approximately 9% to 16% higher yield per additional production month. Model-predicted yields are presented in Fig. 5.

Table 3
Sensitivity analyses

Sensitivity analysis	Duration result	Species result	Interpretation
Household random-intercept model	β = 0.143, t = 8.02	β = 0.236, t = 2.30	Positive duration association retained; ICC = .735 but unstable because 95.6% of households were singleton clusters
Excluding 47 Tukey far-outliers (n = 634)	β = 0.086, p < .001	β = 0.286, p = .008	Duration association remained positive, although attenuated
Conventional non-clustered standard errors	β = 0.149	β = 0.155	Coefficients identical; standard errors were similar to clustered estimates
Spearman rank correlations	ρ = .298 to .306, both p < .001	Not applicable	Positive bivariate association confirmed without distributional assumptions

Note. Source: Own compilation from SIHBS 2022, Livestock_byproducts module.

Discussion

This study examined whether household-level production duration was associated with average monthly milk yield among cow- and camel-milk producing households in the SIHBS 2022 Livestock_byproducts module. Production duration was positively associated with average monthly milk yield in both cow- and camel-milk records. In the primary model, each additional month of reported production was associated with 16.0% higher average monthly yield. This result was retained in analyses using a random-intercept model, conventional standard errors, an outlier-restricted sample, and Spearman correlations. By contrast, the adjusted difference between camel and cow milk was not statistically significant.

The observed association is consistent with the broader concept that sustained production over time is related to milk output. In dairy cattle, management conditions that influence lactation persistency, including milking frequency and nutrition, are associated with cumulative milk yield (Bateki et al. 2020; Strapáková et al. 2016; Torshizi et al. 2019). In camel systems, feeding, calf management, health, and other herd conditions can influence lactation length and milk offtake (Chamekh et al. 2020; Kashongwe et al. 2017; Nagy and Juhász 2016; Nagy et al. 2022). The present finding extends this general pattern to a household-level measure of production continuity across two dairy species surveyed in the same national dataset.

However, production duration in this study is not equivalent to individual-animal lactation persistency. The household measure may reflect multiple lactating animals, staggered calving, herd composition, and management practices. It may also be associated with unmeasured variables that influence yield, including herd size, parity, animal age, health, feed availability, and reproductive status (Kheirabadi et al. 2021; Mukasafari et al. 2025). Consequently, the results do not show that increasing production duration

will cause a 16.0% increase in yield. Rather, households reporting longer periods of milk production also reported higher monthly yields.

The non-significant adjusted species effect should not be interpreted as proof that cow and camel milk yields are identical. The confidence interval included both a modest cow-milk advantage and a substantial camel-milk advantage. It indicates that, in this dataset and after adjustment for production duration, there was insufficient evidence of a precise, independent species difference in monthly yield. This result is compatible with research emphasizing management and environmental influences on milk production in pastoral camel systems (Hassan et al. 2026; Nagy et al. 2022).

From a production perspective, the findings suggest that continuity-oriented management may be a useful focus for future research and extension. Practices related to animal health, feed and water availability, reproductive management, and calf management may help sustain milk production, but the present dataset cannot identify which practices account for the observed association. Future longitudinal studies should link household production records to individual animals, calving dates, parity, feeding, health, and repeated milk measurements (Getaneh et al. 2019; Migose et al. 2020).

Study strengths and limitations

The principal strength of this study is its use of the SIHBS 2022 Livestock_byproducts module, part of a nationally representative household survey, which permitted comparison of production duration and monthly milk yield across both cow- and camel-milk producing households within a single, consistent national dataset. The use of household-clustered robust standard errors, multiple sensitivity analyses, and explicit distinction between household-level production continuity and animal-level lactation persistency are methodological strengths that support the credibility of the reported association.

This study has several limitations. First, the cross-sectional observational design cannot establish temporal order or causality between production duration and milk yield.

Second, milk quantity and production duration were household-reported measures and may be affected by recall error, rounding, or reporting error (Migose et al. 2020; Zezza et al. 2016).

Third, the measures were household-level and were not linked to individual-animal lactation curves.

Fourth, important variables, including herd size, breed or ecotype, animal age, parity, health, feeding, calving date, and reproductive status, were unavailable in the Livestock_byproducts module and could not be controlled for (Bateki et al. 2020; Kheirabadi et al. 2021; Mukasafari et al. 2025).

Fifth, the analysis was restricted to litre-reported records because no documented conversion was available for kilograms or “other” units; this restriction may affect representativeness of the analytic sample relative to all milk-producing households in the survey.

Sixth, this study does not incorporate SIHBS 2022 survey weights, strata, or primary sampling unit identifiers in the regression models; the reported associations should therefore be interpreted as applying to the analysed household-product records rather than as weighted national estimates.

Seventh, the random-intercept sensitivity model produced an intraclass correlation coefficient of .735, but this estimate is unstable because 95.6% of households contributed only one product record (singleton clusters).

Eighth, two discrepancies were present in the source robustness-analysis narrative during manuscript preparation: reported narrative duration coefficients of 0.155 and 0.069 did not match the directly printed table coefficients of 0.143 and 0.086, respectively. The table coefficients were retained here because they were the directly reported model-output values; the original analysts should verify these results against the underlying model objects before submission.

Conclusions and recommendations

Among 681 household-product records from 652 households in the SIHBS 2022 Livestock_byproducts module, longer reported milk-production duration during the preceding 12 months was consistently associated with higher average monthly milk yield in both cow- and camel-milk systems. Each additional production month was associated with an estimated 16.0% higher yield in the primary model. Species identity was not a statistically significant independent predictor of monthly yield after adjustment for production duration. These findings support household production continuity as a relevant correlate of dairy productivity in this sample, while emphasizing the need for longitudinal, animal-level studies to determine the underlying biological and management mechanisms.

Based on these findings, the following recommendations are proposed. First, extension and livestock-development programmes in Somalia should consider production continuity, rather than species alone, as a practical household-level indicator when targeting support for dairy productivity. Second, future household surveys, including subsequent rounds of the SIHBS, should consider collecting complementary animal-level information, such as herd size, parity, calving dates, and health status, to allow the mechanisms underlying the duration–yield association to be tested directly. Third, researchers using the Livestock_byproducts module should document unit-conversion methods for non-litre quantities to reduce sample restriction and improve representativeness in future secondary analyses. Finally, national statistical authorities and research partners should support longitudinal, animal-level data collection linked to household surveys to clarify whether continuity-oriented management practices causally improve milk yield in agro-pastoral cow and camel systems.

Declarations

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Competing interests

The authors declare no competing interests.

Author contributions

Ali Abdulle Omar: Conceptualization; Methodology; Software (R); Formal analysis; Data curation; Visualization; Writing original draft; Writing—review and editing.

Nur Mohamud Ali: Conceptualization; Methodology; Formal analysis; Validation; Investigation; Writing—review and editing.

Data availability

This study did not involve primary data collection. The findings are based on secondary data from the Livestock_byproducts module of the 2022 Somalia Integrated Household Budget Survey (SIHBS), which is publicly accessible through the Somalia National Bureau of Statistics microdata catalogue at https://microdata.nbs.gov.so

Ethics approval

This study used secondary data and did not involve direct contact with animals or human respondents. The dataset is openly and freely available through the official Somalia National Bureau of Statistics (SNBS) website. Therefore, ethical approval was not required for the present study. The researchers confirm that all procedures complied fully with applicable laws and ethical guidelines.

Consent to participate

Not applicable.

Consent to publish

Not applicable.

Statement of animal rights

This study was a secondary analysis of household survey data and did not involve direct animal experimentation, animal handling, or collection of animal biological samples.

Generative AI disclosure

An AI language tool (ChatGPT) was used strictly for language refinement, grammar correction, and copyediting during preparation of the draft. The tool was not used for study design, data collection, statistical analysis, or drawing conceptual conclusions. The authors reviewed and edited all AI-assisted text and take full responsibility for the content of this manuscript.

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Figures

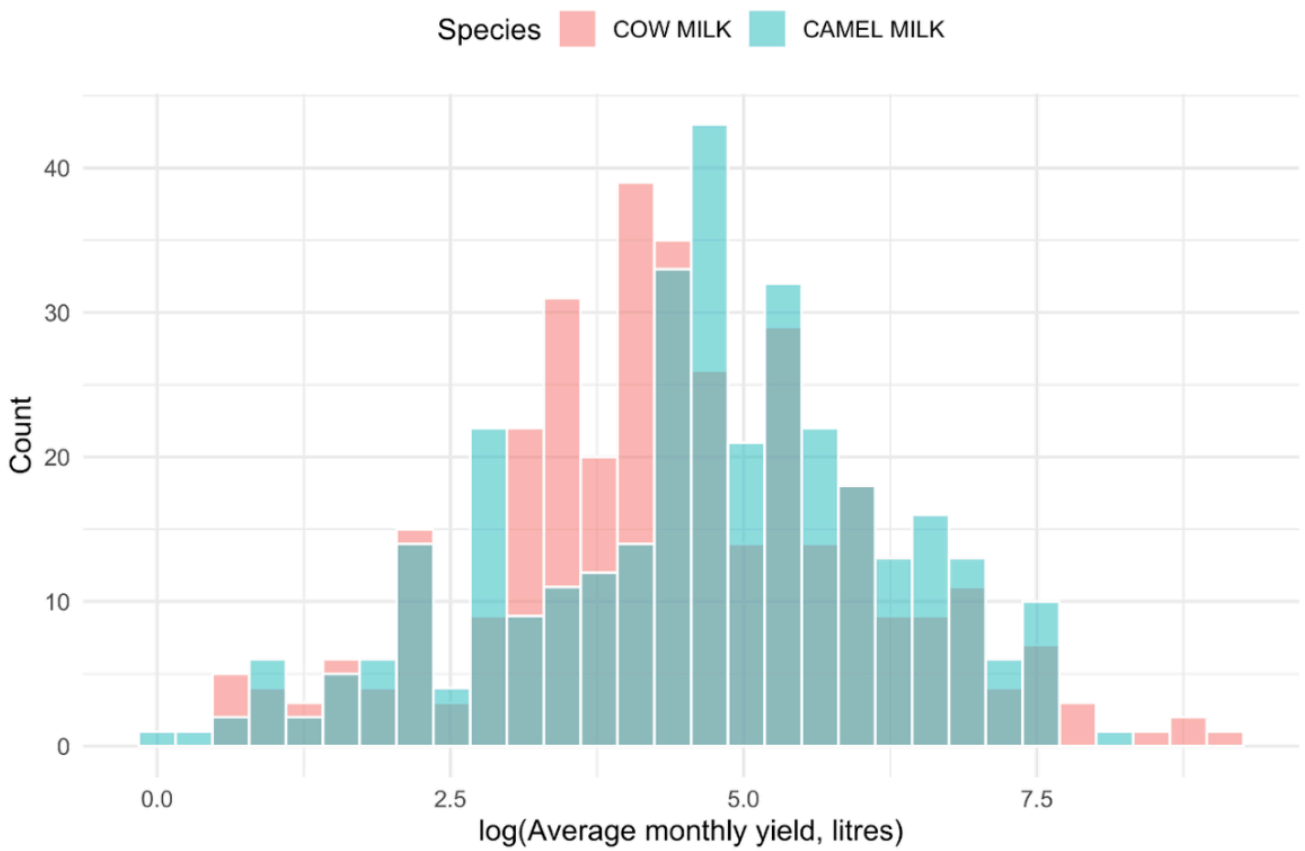


Figure 1

Distribution of average monthly milk yield on the natural-log scale, by species. The log-transformed distributions for both species are approximately symmetric and substantially overlapping, supporting use of the log scale as the model outcome

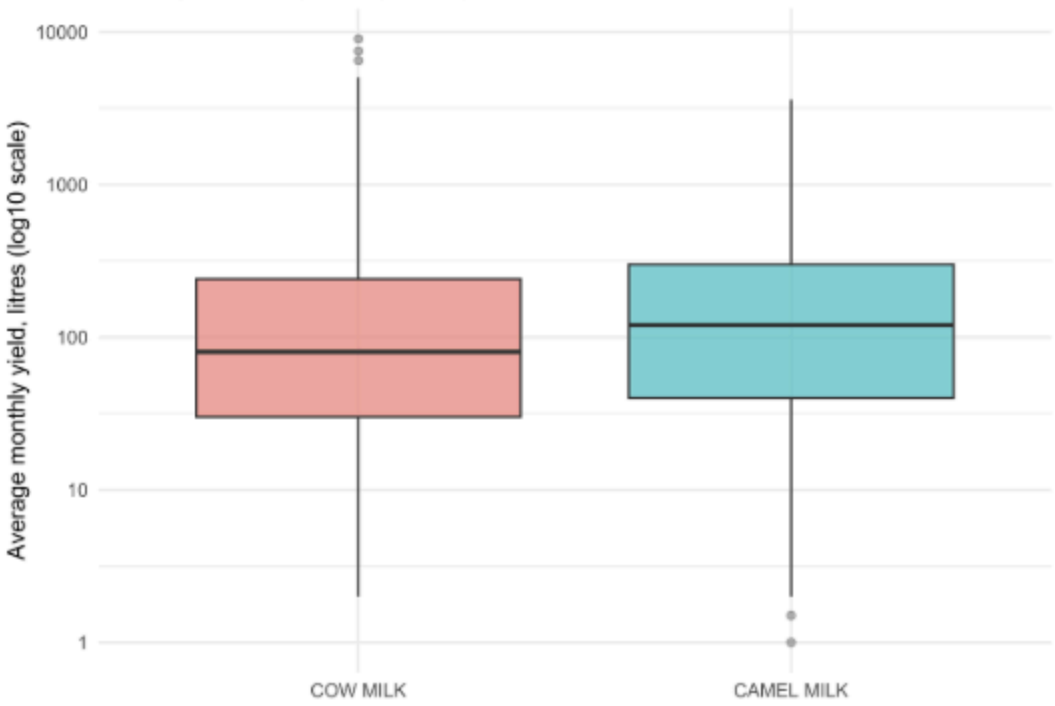


Figure 2

Average monthly milk yield by species (log10 scale). Camel milk shows a numerically higher median and a wider interquartile spread than cow milk; both species show pronounced high-value outliers

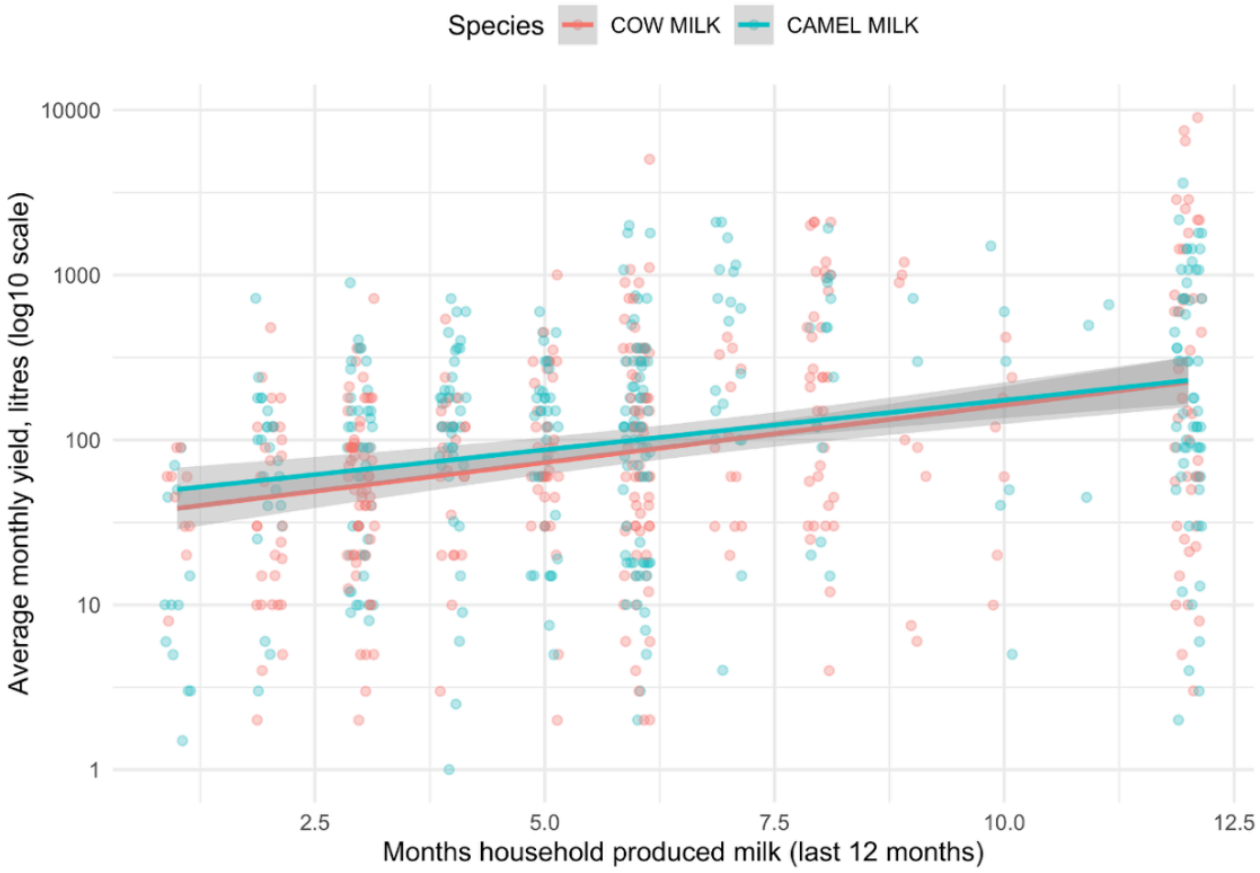


Figure 3

Production duration versus average monthly milk yield by species (log10 scale; linear fits with 95% confidence bands). Both species show an upward trend in yield with increasing production duration

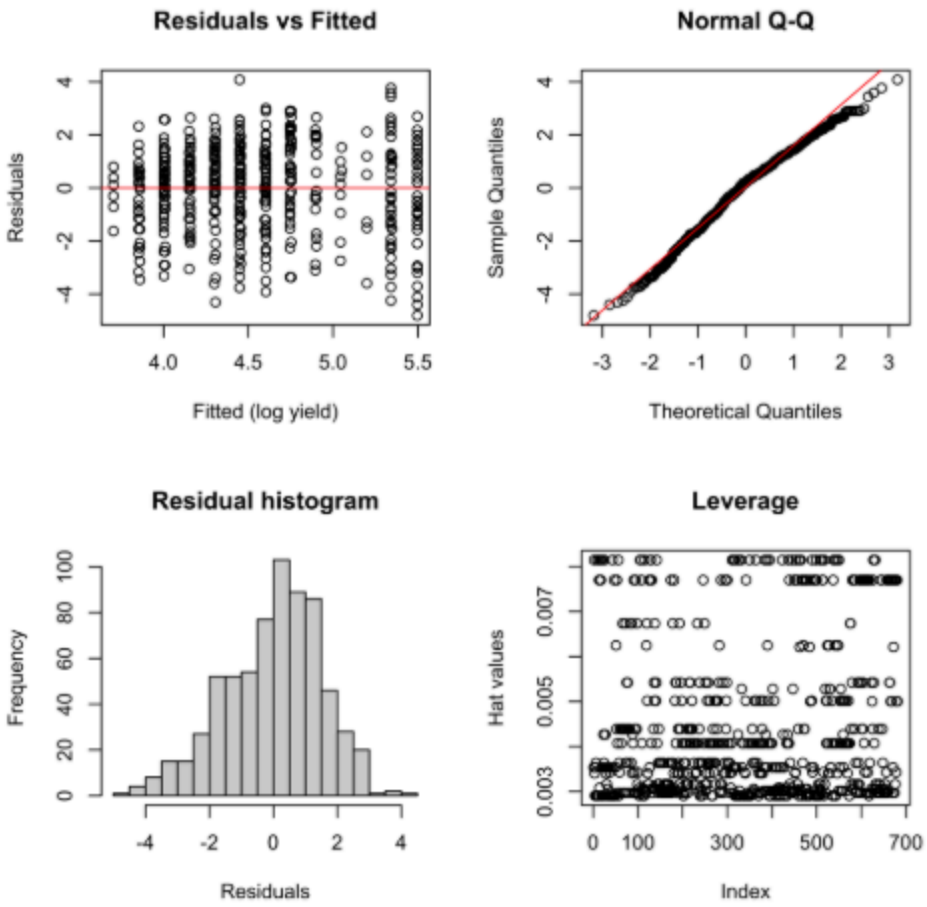


Figure 4

Diagnostic plots for the primary model: residuals versus fitted values, normal Q–Q plot, residual histogram, and leverage values

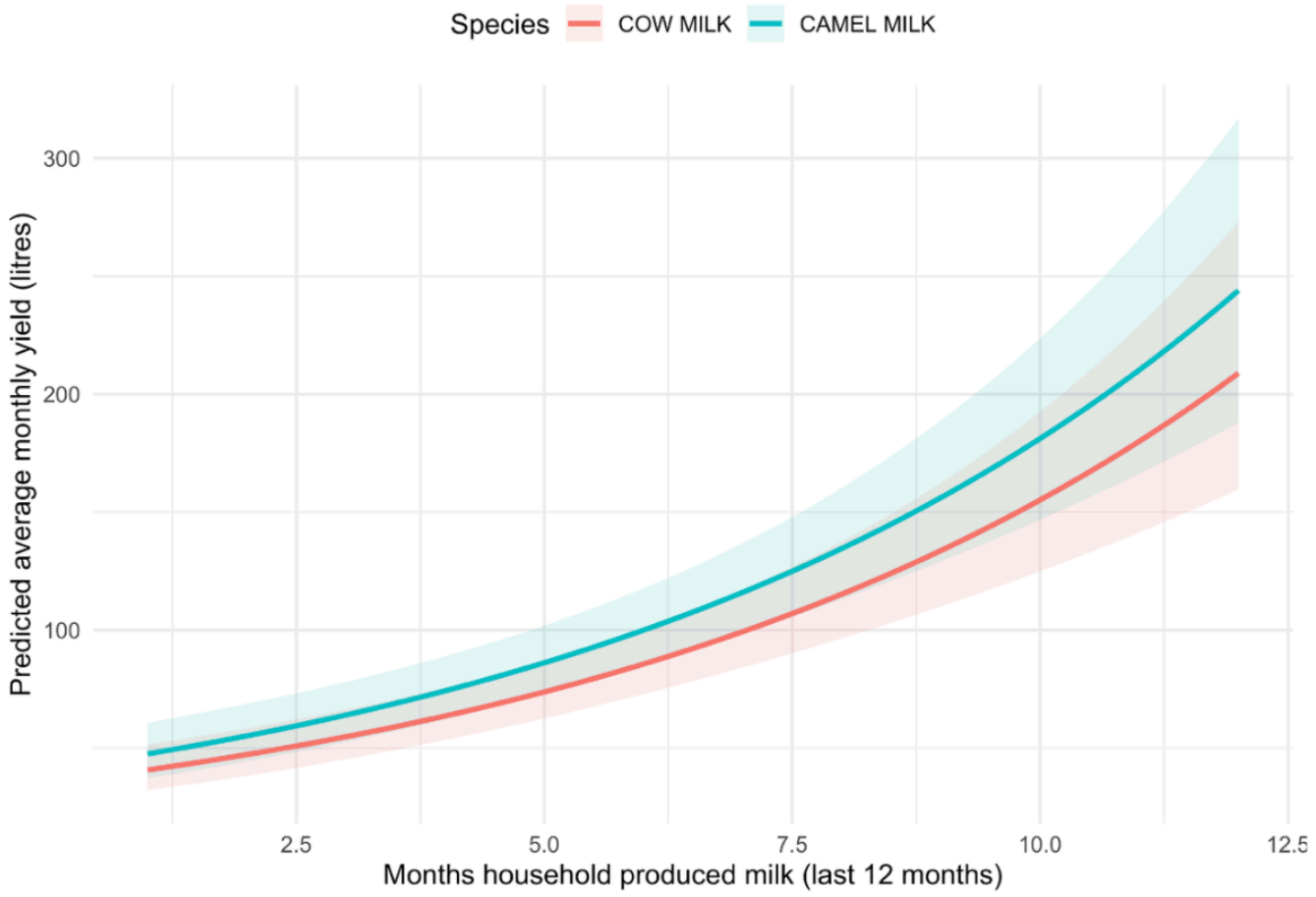


Figure 5

Model-predicted average monthly milk yield by production duration and species, back-transformed from the log-scale model with 95% confidence bands