Effect of parity in different grazing seasons on milk yield and composition of cattle × yak hybrids in the Himalayan alpines

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ABSTRACT
This study assessed the effect of parity in different seasons on the milk yield and composition of lactating cattle × yak hybrids (Dimjo Chauries) in the Nepalese Himalayan alpines. A pasture site typically grazed in summer and autumn was selected at 4200 m.a.s.l. The experimental animals were grouped into 2nd, 4th, and 6th parity groups (n = 18). The pasture characteristics, and milk and body parameters of the animals were measured in both seasons. Parity and season had a significant effect on the body weight of lactating hybrids, and almost constant daily weight gain was observed in 4th parity Chauries. The daily milk yield and fat content were affected by both season and parity, whilst parity did not affect milk protein or lactose content. The highest daily milk yield was obtained from the 6th parity Chauries in summer (3.42 kg d⁻¹) with unchanged fat content, and the lowest (1.46 kg d⁻¹) was from the 2nd parity in autumn. This implies that the older parity cattle × yak hybrids, especially of the 4th parity, are promising for persistently higher milk yield and composition than that of 2nd and 6th parity hybrids.

Introduction
Hybridization of cattle (Bos taurus) with yaks (Bos grunniens) is traditional in the herding communities in the Himalayan alpines of Nepal (Palmieri 1987; Bishop 1989). The females thus produced, locally called Dimjo Chauries, are fertile (Palmieri 1987) and serve multiple purposes (Phillips et al. 1946). They form one of the sources of livelihood (Thapa 2002; Guo et al. 2012), and are kept under traditional transhumance system (Wilson 1997). In the transhumance system, animals utilize the rangelands of higher altitudes during summer, and gradually move towards lower altitudes in winter (Degen et al. 2007; Dong et al. 2009). The intensity of animal movement and camping for herding at different pastures varies by animal species, pasture availability, and prevailing weather conditions and altitude of the pasture sites. The cattle × yak hybrids have a similar high altitude tolerance to that of purebred yaks, but have higher milk yield, even at lower altitudes (Barsila et al. 2014), when managed under low stocking density (Barsila et al. 2015). Hybrids have an advantage of heterosis in milk yield and fat content over that of purebred yaks (Wang et al. 1994). The cattle × yak hybrids have better feed utilization efficiency than cattle (Wang et al. 2011), e.g. in terms of roughage utilization (Bao et al. 2011), which might be attributed to its yak parent. In addition, other milk quality characteristics of the offspring can be attributed to either the yak or cattle parent e.g. higher minerals and essential amino acids content (Li et al. 2010, 2011), with some compounds having anti-inflammatory properties (Mao et al. 2011; Nikkhah 2011). Moreover, some milk properties of its yak parent’s e.g. essential fatty acids, vary between seasons and parity (Liu et al. 2011), but it differs in its hybrid off-spring (Marquardt et al. 2018). Information on the milk yield potential of cattle × yak hybrids across the grazing season is limited, as these animals are kept in transhumance in remote areas of the Himalayan mountains of Nepal. In the Kanchenjunga Conservation Area of Nepal, the herders of Olangchung Gola usually bring the herd to 4200 m (Mauma pastures) in July during upward movement and the same sward is also grazed in September, during the downward movement. Scientific evidence suggest that older parity cattle and their crossbreeds are more resilient to lower forage quality and availability. However, limited research is available on the effects of parity and grazing season on milk yield and composition of cattle × yak hybrids reared in the Himalayan alpine rangelands of Nepal. The milk yield and composition of cattle × yak hybrids might be influenced by the seasonal changes and parity in the alpine transhumance settings. It is hypothesized that, with the increase in parity, there is an increase in milk production, and further expected that the older parity cattle × yak hybrids are more resilient than younger ones to the consumption of low-quality herbage during grazing in the Himalayan alpine, whilst maintaining the milk yield and quality.

Materials and methods
Experimental design
Site selection
In the Kanchenjunga Conservation Area (KCA) of Nepal, a traditional transhumant route was identified in consultation with the local herders and a high altitude (4200 m) pasture was selected. There were more than 20 different pasture sites (covering about 15 km in length at an elevational of 2000-
5000 m.a.s.l.) available at different altitudes along the transhumant route. The pasture site is free for grazing to the local herders and herds usually arrive by July from the lower altitude pasture sites and again in September during the gradual downward movement.

The experimental pasture site ~40 ha in size and was always grazed by purebred yaks and their hybrids with cattle during upward (seasonal vegetation) and downward (re-growth of vegetation) movement of the transhumance cycle. The main entry point was fenced to prevent alteration of the vegetation in both the July and September experiments.

Weather record
A portable weather station was manually installed for both measurement periods i.e. in July and September. Weather variables, such as temperature, humidity, and rainfall, were recorded for a limited experimental period (15 days) during both experimental periods. The maximum temperature recorded was ~18°C in summer (July) and the minimum temperature in September was ~2°C. The average relative humidity was ~71% and ~55% in July and September, respectively. There was ~5 mm of rainfall in June, whilst it was only ~0.5 mm in September.

Animal ethics
Nepal has not yet officially established a system for ethical approval of animals in experiments. All the processes involving animals followed the international guiding principles listed by the Council for International Organizations of Medical Sciences and the International Council for Laboratory Animal Science (2012).

Selection of animals
The cattle × yak hybrids used in the experiments were traditionally hybridized off-spring of female Nepalese yaks, called naks (Bos grunniens), and male Tibetan cattle (Bos taurus), managed in the transhumance system. The experimental lactating cattle × yak hybrids were selected and assigned to 2nd, 4th, and 6th parity groups.

When the herd arrived at 3200 m (June) during the upward transhumance movement, a herd milk production record was established and daily milk yield was recorded for 15 days to select the experimental animals. Further information on parturition and parity were obtained from the local herder.

Milking hybrids of 2nd, 4th, and 6th parities were selected based on the similarity of milk yield within parity groups from the same herder. The average milk yield of the 2nd parity group was ranging from 2.29 to 2.35 kg/day, 2.45 to 2.50 kg/day for 4th parity and it remained 2.57–2.60 kg/day for the 6th parity groups. The animal selection was further marked at the similarity in the date of parturition that did not exceed more than a week within each parity group (Table 1). Each group consisted of six lactating hybrids, selected from a herd of 60 animals. The selected animals were kept with the herd throughout the experimental period (July and September) and were used for data collection (milk yield and composition) in July and September, without altering the traditional transhumance practices of the herder. Details of the selection of milking cattle × yak hybrids are shown in Table 1.

Estimation of aboveground herbage mass and botanical composition
Herbage mass measurements in the swards were carried out in July (summer) and September (autumn; re-growth) in the same pasture during upward and downward movement, respectively. One day before the herd arrived at the experimental pasture site at 4200 m, the botanical composition and plant cover were estimated from 50 random transects of 1 m × 1 m, using the Braun-Blanquet cover-abundance scale (Bonham 2013). The herbage was harvested above 2 cm from the ground and weighed for green mass accordingly to the botanical groups. The herbage samples were mixed together and oven-dried at the Animal Nutrition Laboratory of Agriculture and Forestry University, Nepal, and later the herbage dry mass was calculated.

Analysis of the herbage chemical composition
The representing forage samples were later oven-dried at 60°C until it reached a constant weight, then milled to a 45 mm mesh size. Chemical analyses were performed following the methods of AOAC (1997) and Van Soest (1991) at the laboratory of the Division of Animal Nutrition of Nepal Agricultural Research Council, Khumaltar, Lalitpur, Nepal. The major components analyzed were: organic matter (OM), crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF), and acid detergent lignin (ADL). Moreover, hemicellulose and cellulosic content were calculated.

Measurement of body weight
Body weight was measured on the day when the herd arrived at 4200 m by using a digital balance (max. capacity of 500 kg and 99.9% accuracy). The body weight of the experimental animals was measured again in August (after 30 days) whilst the herd was at 4500 m in the intermediary pastures of the same transhumance route during upward movement. The final body weight measurement was done in September during the autumn phase of the experiment, during the downward movement. The daily weight gain was calculated twice i.e. for the initial 30 days (body weight in August–body weight in July) and for the final 30 days (body weight in September–body weight in August).

| Parity | Number of Animals | Milk yield, kg day⁻¹ | Body weight kg | Calving date |
|--------|------------------|----------------------|----------------|-------------|
| 2nd    | 2                | 2.29, 233            | 15th April     |
| 2      | 2                | 2.31, 230            | 20th April     |
| 2      | 2                | 2.35, 231            | 22nd April     |
| 4th    | 2                | 2.45, 244            | 16th April     |
| 2      | 2                | 2.47, 245            | 19th April     |
| 2      | 2                | 2.50, 242            | 22nd April     |
| 2      | 2                | 2.57, 256            | 15th April     |
| 2      | 2                | 2.59, 257            | 18th April     |
| 2      | 2                | 2.60, 254            | 21st April     |

Table 1. Description of selection of cattle × yak hybrids and their parity for the experiment in 2017.
Daily milk yield record and analysis of milk composition

Daily milk yield and composition were analyzed for seven days during both measurement periods following a 15 day adaptation period each time. Lactating hybrids were hand-milked by the same herder, without calves, both in the morning (7:00 am) and evening (17:00) accordingly to the herder’s traditional practice. The daily milk yield (morning and evening) was recorded using a digital balance (max. capacity of 5 kg and an accuracy of 99%). The milk composition was analyzed with a solar power-operated ultrasonic milk Lactoscan (Milkotronic Limited, Bulgaria). Further, energy-corrected milk by following ALP (2013), daily fat, protein, and lactose yields were calculated. The aliquot technique was used to calculate the milk constituents from a total of the morning and evening milk yield and constituents data, following Barsila et al. (2015).

Statistical analysis

The milk yield and composition data obtained were analyzed without calibration (see Barsila et al. 2014) as the sites were in remote areas where transport of milk to nearby research stations was impossible.

In the statistical analyses, two variable factors i.e. parity and season (represented by grazing month) and their interaction were considered. Further, only the seasonal effect on herbage mass productivity and botanical groups of the herbage was considered. Data were analyzed using the mixed procedure of SAS (version 9.1). The mean differences were obtained at the 5% level of significance using Tukey’s test. The following two-way analysis of variance model was designed for the analysis of milk yield and composition:

\[
y_{ijkm} = \mu + s_i + p_j + sp_{ik} + e_{ijkm}
\]

(1)

Where, \(y_{ijkm}\) = Individual observation for parameter \(Y_{ijk}\); \(\mu\) = Overall mean for parameter \(Y\); \(s_i\) = Fixed effect of the \(i\)th season (month); \(p_j\) = Fixed effect of the \(j\)th parity; \(sp_{ik}\) = Fixed effect of the \(i\)th season (month) and parity interaction; \(e_{ijkm}\) = Residual error.

For herbage mass and botanical composition, the following one-way analysis of variance model was used for data analysis:

\[
y_{ij} = \mu + m_j + +e_{ij}
\]

(2)

Where, \(y_{ij}\) = Individual observation for parameter \(Y_{ij}\); \(\mu\) = Overall mean for parameter \(Y\); \(m_i\) = Fixed effect of the \(i\)th season (month); \(e_{ij}\) = Residual error.

Results

Pasture characteristics

Herbage cover

Altogether, 65 different vascular plant species were recorded (excluding unknown ferns and algae), whilst 60 could be identified to species level and 15 to genus level only. A shift in herbage cover from herbs (forbs) to grasses and cyperus was observed. Among the highly abundant herbage species, *Poa himalayana* and *Ranunculus hirtellus* covered 30% of the area; whilst in September, *Kobresia nepalensis* and *P. himalayana* were dominant. Details of the herbage cover are presented in Table 2.

Herbage botanical composition

The effect of season was highly significant on the total dry-weight content of the pasture. The herbage (forbs) were significantly higher in July but declined to 30% in September, which was the opposite of the contribution of grasses and cyperoids. Details of the aboveground herbage mass and the contribution of the botanical groups are presented in Table 3.

Herbage chemical composition

The organic matter and CP content declined from July to September. In contrast to the measurements made in July, the coarseness (fibrous residues) was higher in September, unless the cellulose content was lower (Table 3).

Body weight gain

Both season and parity had a significant effect (\(p < 0.05\)) on the body weight of lactating hybrids (Table 4). In September, the initial body weight was the highest in 6th parity hybrids and daily weight gain in the 4th and 6th parity hybrids was more rapid than that of the youngest parity hybrids (2nd parity). In general, parity had a similar effect on the daily weight gain of the lactating hybrids, but the effect of grazing season remained significant (\(p < 0.05\)).
Milk yield and composition

Daily milk yield, ECM, and fat content were significantly affected \( (p < 0.05) \) by season, parity, and their interaction (Table 4). The highest daily milk yield was obtained from 6th parity hybrids \( (3.42 \text{ kg day}^{-1}) \) in July and the lowest was obtained from 2nd parity groups in September \( (1.5 \text{ kg day}^{-1}) \). There was also a similar trend in energy-corrected milk yield.

Milk fat content was highest in September \( (8.30\%) \) in the 4th parity hybrids (Table 4). Milk protein and lactose content were significantly higher \( (p < 0.05) \) in July than in September, due to advancing lactation and changes in the growth stages of the herbagess (Table 2). The daily output of fat \( (185.10 \text{ g in July vs. 149.37 g in September}) \), protein \( (91.03 \text{ g vs. 61.60 g}) \), and lactose were significantly affected \( (p < 0.05) \) by season, parity, and their interaction (data not shown).

Discussion

Effect on daily weight gain

In the present study, both parity and month of grazing had a significant effect on the body weight gain of lactating cattle × yak hybrids. The differences in daily weight gain between the different parity groups might be associated with the physiological adjustments to milk production performance. Daily body weight gain is an indicator of the energy supply (Long et al. 1999) that comes from the herbagess. The highest body weight gain was obtained from 6th parity hybrids (3.42 kg day\(^{-1}\)) in July and the lowest was obtained from 2nd parity groups in September (1.5 kg day\(^{-1}\)).

Table 3. Above-ground herbage dry mass harvested from the experimental pasture site over two different seasons of grazing at 4200 m above sea level in the Kanchenjunga Conservation Area of Nepal.

| Parameters | Season | Parity groups | 1SEM | \( p \)-value |
|------------|--------|---------------|------|--------------|
| Initial body weight, kg | July (Summer) | 232e | 248cd | 260bc | 3.05 | <0.001 | <0.001 | 0.153 |
| September (Autumn) | 236e | 263bc | 274a | | | | |
| Daily weight gain, kg day\(^{-1}\) | Aug.-July | 0.60e | 0.34bc | 0.09bc | 0.06 | 0.041 | 0.068 | <0.001 |
| Sept.-Aug. | 0.46c | 0.17c | 0.55bc | | | | |
| Absolute milk yield, kg day\(^{-1}\) | July (Summer) | 2.15c | 2.70bc | 3.42a | 0.17 | <0.001 | <0.001 | <0.01 |
| September (Autumn) | 1.46d | 2.44bc | 1.81cd | | | | |
| ECM, kg day\(^{-1}\) | July (Summer) | 2.56cd | 3.58bc | 4.78a | 0.24 | <0.001 | <0.001 | <0.001 |
| September (Autumn) | 2.03d | 3.67bc | 2.54cd | | | | |
| Fat % | July (Summer) | 5.60d | 6.79e | 7.40b | 0.14 | <0.001 | <0.001 | <0.001 |
| September (Autumn) | 7.50b | 8.30e | 7.50b | | | | |
| Protein % | July (Summer) | 3.36 | 3.35 | 3.24 | 0.04 | 0.020 | 0.226 | 0.206 |
| September (Autumn) | 3.19 | 3.27 | 3.23 | | | | |
| Lactose % | July (Summer) | 4.72 | 4.73 | 4.56 | 0.06 | 0.013 | 0.217 | 0.201 |
| September (Autumn) | 4.48 | 4.59 | 4.55 | | | | |

\( ^1 \)Pooled SEM across the months and parity groups. Months represents the summer and autumn seasons in the local transhumance system.

\( ^2 \)Body measurements done only at the start of data collection in July (arithmetic mean and SEM presented). First 30 days daily weight change = body weight in August minus body weight in July; and second 30 days weight change = body weight in September minus body weight in August.

\( ^3 \)ECM calculated following ALP (2013).

Milk yield and composition

Daily milk yield, ECM, and fat content were significantly affected \( (p < 0.05) \) by season, parity, and their interaction (Table 4). The highest daily milk yield was obtained from 6th parity hybrids \( (3.42 \text{ kg day}^{-1}) \) in July and the lowest was obtained from 2nd parity groups in September \( (1.5 \text{ kg day}^{-1}) \). The daily milk yield of 4th parity lactating hybrids was similar in July and September \( (2.70 \text{ vs. 2.44 kg day}^{-1}) \). There was also a similar trend in energy-corrected milk yield.

Milk fat content was highest in September \( (8.30\%) \) in the 4th parity hybrids (Table 4). Milk protein and lactose content were significantly higher \( (p < 0.05) \) in July than in September, due to advancing lactation and changes in the growth stages of the herbagess (Table 2). The daily output of fat \( (185.10 \text{ g in July vs. 149.37 g in September}) \), protein \( (91.03 \text{ g vs. 61.60 g}) \), and lactose were significantly affected \( (p < 0.05) \) by season, parity, and their interaction (data not shown).
weight gain in the 6th parity group could be due to the fact that
the animals reached their adult size and optimum body metab-
olism, leading to greater daily body weight gain, provided that
enough forage was available from July to September. There is
sometimes a decline of up to one-third of the body weight of
Chinese yaks during winter (Xue et al. 2005). Whilst the higher
daily weight gain in 4th and 6th parity animals than that of
young animals would be due to optimum body metabolism,
resulting in low energy partition for a thermoregulatory mecha-
nism (Khan et al. 1992). It might also be possible that young
animals do not have optimum digestibility of forage compared
to that of adults. As expected, the body weight gain during the
first month of observation was higher than that in the second
month. This could be due to the fact that there was optimum
good quality herbage available during the experimental obser-
vation in July, and the forage quality might have degraded or
matured in September, resulting in low body weight gain in
the latter case.

**Effect on milk yield and milk components**

The highest daily milk yield and energy-corrected milk (ECM) was
found in the 6th parity lactating hybrids in July, which could have
been due to the quality of herbage and the effect of lactation
stage, as reported previously by Gyamtsho (2000). In contrast,
low milk yield in the 2nd parity group could be due to animal-
related factors, i.e. animals in the 2nd parity group had not
reached full production potential by that time, due to age-
related phenomena. Milk fat content gradually increased from
July to September whereas lactose and protein content gradually
decreased. The higher milk fat content in September than in July
could be due to the advancing stage of lactation and increased
fibre content of the herbage. When lactation stage advances,
milk yield declines, and the milk constituents increase (Ostersen
et al. 1997). The stage of lactation, together with the changing
pasture quality, would probably provide the best reasons why
milk yield declined more during the measurements in September
and contrast, had the highest milk fat content. Here, the trend of
higher milk fat content in September was in agreement with the
physiological changes in milk-producing hybrids with alteration
in forage chemical composition and the fibre content of the diet (Leibet al. 2006; Ferlay et al. 2006). The higher protein
and lactose content in July milk were probably due to surplus
high-quality forage compared to that in September, when the
herbages in Himalayan alpine pastures start to mature and ul-
timately fade away.

Purebred yaks are efficient in fibrous feed utilization (Bao
et al. 2011) whilst it is expected that their hybrids with cattle
might also have gained such genetic merit. Here, the higher
milk protein and lactose content in July is corroborated by
the fact that, by that time, forage had optimal growth with
low fibre content i.e. high propionic acid production from
rumen fermentation which is utilized directly for lactose and
protein synthesis (Storry and Sutton 1969).

The decrease in milk protein content in September further
indicated a severe shortage in energy and protein supply by
the herbage (Brun-LaFleur et al. 2010), which showed the
reduced requirements for the formation of these milk constitu-
ents because of the progressing stage of lactation (Rook and
Line 1961). During September, animals might have gone
through severe energy and protein supply shortages, which
might have reduced the formation of milk constituents as
energy and protein partitioning is the lowest priority for such
productive traits e.g. milk production during the period of nutri-
ten deficiency. In the present study site, alpine pastures reach
maturity in September, with high fibre content that probably
resulted in relatively high rumen acetate concentrations,
which could be the reason for the higher milk fat content in
milk of any parity groups. The variation found in milk yield
and energy-corrected milk (ECM) could be attributed to vari-
ation in the quality and quantity of the available forage, and
interaction between parity and forage quality. The decline in
milk yield, rapid body weight gain in 6th parity groups, and sig-
nificant weight loss and low milk yield in 2nd parity hybrids are
indicative of rapid changes in body reserves (Rook 1976) for
production in lactating hybrids that are either too young (2nd
parity) or too old (6th parity). It would further indicate that
older parity hybrids are adapted to lower quality herbage
intake than the younger lactating hybrids (2nd parity). Results
of a cattle experiment by Amasaib et al. (2011) indicated that
parity affects the total milk yield. In the present study, milk fat
content was also found significantly affected by parity and
grazing season and could be associated with the lactation
length, which cannot be excluded from the measured milk-
related parameters. The measurement period in July is the
peak milk yielding season for hybrids and from then onwards,
milk yield declines and the fat content in milk increases.

**Conclusions**

This experiment carried out in the eastern Himalaya of Nepal
revealed that cattle × yak hybrids with older parities (4th pari-
ties) would be more promising for commercial herding than
younger parities (2nd parity), as shown by their persistently
higher daily milk yield and daily outputs of milk constituents
in two different grazing seasons. The findings can further docu-
mence the performance of cattle × yak hybrids and suggest the
optimal selection of lactating hybrids for commercial herding
in the Himalayan alpine rangelands setting at least at 4th
parity. Moreover, the heterotic potential in milk yield and com-
position is yet to be determined for cattle × yak hybrids grazing
in the transhumance system. A detailed rangeland inventory
and grazing behaviour studies are needed to confirm the
findings of the present study.

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References

Agroscope Liebefeld-Posieux (ALP). 2013. Fütterungsempfehlungen und Nährwerttabellen für Wiederkäuer Feeding Recommendations and Nutrient Tables for Ruminants. (http://www.agroscope.admin.ch/futtermitteldatenbank/04834/index.html?lang=de) (accessed April, 2019).

Amasaib EO, Fadel-Elseed AM, Mahala AG, Fadlelmoula AA. 2011. Seasonal and parity effects on some performance and reproductive characteristics of crossbred dairy cows raised under tropical conditions of the Sudan. Lives Res Rural Dev. 23:1–6.

AOAC. 1997. Official methods of analysis. Arlington, VA, USA: Assoc. Off. Anal. Chem.

Bao L, Huang Q, Chang L, Zhou J, Lu H. 2011. Screening and characterization of a cellulase with endocellulase and exocellulase activity from yak rumen metagenome. J Molec Catal B: Enzyme. 73:104–110.

Barsila SR, Devkota NR, Kreuzer M, Marquardt S. 2015.Evaluation of breeding systems and factors affecting productivity and reproduction in yak cows. Prev Vet Med. 118(2015):195–202.

Barsila SR, Devkota NR, Kreuzer M, Leiber F, Marquardt S. 2015. Effects of different stocking densities on performance and activity of cattle × yak hybrids along with a transhumance route in the eastern Himalaya. SpringerPlus. 4:398.

Barsila SR, Kreuzer M, Devkota NR, Ding L, Marquardt S. 2014. Adaptation to Himalayan high altitude pasture sites by yaks and different types of hybrids of yaks with cattle. Lives Sci. 169:125–136.

Bishop NH. 1999. From zomo to yak: change in a Sherpa village. Human Ecol. 17:177–204.

Bonham CD. 2013. Measurements for terrestrial vegetation. New York, USA: John Wiley and Sons.

Brun-Lafleur L, Delaby L, Husson F, Faverdin P. 2010. Predicting energy × protein interaction on milk yield and milk composition in dairy cows. J Dairy Sci. 93:4128–4143.

Council for International Organizations of Medical Sciences and International Council for Laboratory Animal Science. 2012. International guiding principles for biomedical research involving animals. [accessed April, 2019]. Available at: http://www.cioms.ch/images/stories/CIOMS/IGP2012.pdf.

Degen AA, Kam M, Pandey SB, Upreti CR, Pandey S, Regmi P. 2007. Transhumant pastoralism in yak production in the lower Mustang district of Nepal. Nomad People. 11:57–85.

Dong SK, Wen L, Zhu L, Lassio JP, Yan ZL, Shrestha KK, Sharma E. 2009. Indigenous yak and yak-cattle crossbreed management in high altitude areas of northern Nepal: a case study from Rasuwa district. Afr J Agric Res. 4957–967.

Ferlay A, Martin B, Pradel P, Coulon JB, Chilliard Y. 2006. Influence of grass-based diets on milk fatty acid composition and milk lipolytic system in Tarentaise and Montbéliarde cow breeds. J Dairy Sci. 89:4026–4041.

Guo XS, Zhang Y, Zhou JW, Long RJ, Xin GS, Qi B, Ding LM, Wang HC. 2012. Nitrogen metabolism and recycling in yaks (Bos grunniens) offered a forage–concentrate diet differing in N concentration. Anim Prod Sci. 52:287–296.

Gyamtho P. 2000. The economy of yak herders. J Bhu Stu. 209:1–35.

Khan F, Spence VA, Belch JFP. 1992. Cutaneous vascular responses and thermoregulation in relation to age. Clin Sci. 82:521–528.

Leiber F, Kreuzer M, Leuenberger H, Wettstein HR. 2006. Contribution of diet type and pasture conditions to the influence of high altitude grazing on intake, performance and composition and renneting properties of the milk of cows. Anim Res. 53:37–53.

Li H, Ma Y, Dong A, Wang J, Li Q, He S, Maubois JL. 2010. Protein composition of yak milk. Dairy Sci Tech. 90:111–117.

Li H, Ma Y, Li Q, Wang J, Cheng J, Xue J, Shi J. 2011. The chemical composition and nitrogen distribution of Chinese yak (Maivia) milk. Int J Mol Sci. 12:4885–4895.

Liu HN, Ren FZ, Jiang L, Ma ZL, Qiao HJ, Zeng SS, Gan BZ, Guo HY. 2011. Short communication: fatty acid profile of yak milk from the Qinghai-Tibetan Plateau in different seasons and for different parities. J Dairy Sci. 94:1724–1731.

Long RJ, Zhang DG, Wang X, Hu ZZ, Dong SK. 1999. Effect of strategic feed supplementation on productive and reproductive performance in yak cows. Prev Vet Med. 38:195–206.

Mao XY, Cheng X, Wang X, Wu SJ. 2011. Free-radical-scavenging and anti-inflammatory effect of yak milk casein before and after enzymatic hydrolysis. Food Chem. 126(12):484–490.

Marquardt S, Barsila SR, Amelchanka SL, Devkota NR, Kreuzer M, Leiber F. 2018. Fatty acid profile of ghee derived from two genotypes (cattle–yak vs yak) grazing different alpine Himalayan pasture sites. Anim Prod Sci. 58:358–368.

Nikkhah A. 2011. Science of camel and yak milks: human nutrition and health perspectives. Food Nutr Sci. 2:567–673.

Ostensen S, Foldager J, Hermansen JE. 1997. Effects of stage of lactation, milk protein genotype and body condition at calving on protein composition and renneting properties of bovine milk. J Dairy Res. 64:207–219.

Palmieri RP. 1987. Cattle hybrids among the Sherpa of Nepal. J Cult Geo. 7:89–100.

Phillips RW, Tolstoy JA, Johnson RG. 1946. Yaks and yak-cattle hybrids in Asia. J Heredity. 37:207–215.

Rook JAF. 1976. Nutrition of the cow and its effects on milk quantity and quality. Int J Dairy Tech. 29:129–136.

Rook JAF, Line C. 1961. The effect of the plane of energy nutrition of the cow on the secretion in milk of the constituents of the solids-non-fat fraction and on the concentrations of certain blood-plasma constituents. Brit J Nutr. 15:109–119.

Storry JE, Sutton JD. 1969. The effect of change from low-roughage to high-roughage diets on rumen fermentation, blood composition and milk fat secretion in the cow. Brit J Nutr. 23:511–521.

Thapa T. B. 2002. Diversification in processing and marketing of yak milk based products. In: Jianlin, editor. Yak Production in Central Asian Highlands. Proceedings of the Third International Congress on Yak held in Lhasa, P.R. China, 4–9 September 2000,. Nairobi, Kenya: ILRI (International Livestock Research Institute); p. 484–489.

Van Soest PJ, Robertson JB, Lewis BA. 1991. Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition. J Dairy Sci. 74:3583–3597.

Wang H, Long R, Liang JB, Guo X, Ding L, Shang Z. 2011. Comparison of nitrogen metabolism in Yak (Bos grunniens) and indigenous cattle (Bos taurus) on the Qinghai-Tibetan Plateau. Asian-Australasian J Anim Sci. 24:766–773.

Wang N, Vandepitte W, Wu JC. 1994. Crossbreeding yak (Bos grunniens) and yellow cattle (Bos taurus): simulation of a rotational system and estimation of crossbreeding means and heterosis effects. J Appl Anim Res. 6:1–12.

Wilson RT. 1997. Animal genetic resources and domestic animal diversity in Nepal. Biodiv Conserv. 6:233–251.

Xue B, Zhao QG, Zhang YS. 2005. Seasonal changes in weight and body composition of yak grazing on alpine-meadow grassland in the Qinghai-Tibetan Plateau of China. J Anim Sci. 83:1908–1913.