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Alpaca production in climate-stressed andean agro-ecosystems: Insights from milk composition, pasture quality and management practices

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Abstract

Alpaca production plays a central role in sustaining livelihoods in the high-altitude Andes, where agro-ecosystems are increasingly affected by climate variability, pasture degradation and resource scarcity. In these marginal environments, alpaca systems are often considered inherently resilient; however, their capacity to sustain productivity under changing climatic conditions remains insufficiently understood. It is therefore essential to better understand factors affecting productivity in order to develop climate-resilient and multifunctional agro-ecosystems. This study evaluated how alpaca milk composition varies between primiparous and multiparous females across three lactation stages in three high-Andean regions of Peru (Cusco, Puno, Junín). A total of 158 milk samples were analysed using FOSS MilkoScan and nine pooled native pasture samples were analysed using AOAC, and ANKOM methods. Additionally, ten semi-structured interviews were conducted with local farmers to understand feeding, breeding, and rearing practices under different conditions. Multiparous females ($n = 80$) produced milk with higher fat and protein contents (median 4.46 % and 5.43 %, respectively), while primiparous females ($n = 78$) showed slightly higher lactose levels (median 5.19 %). Across lactation, fat content increased and lactose decreased consistently, whereas protein and non-fat solids remained relatively stable. Regional differences were minor, indicating that physiological factors outweigh environmental variation under extensive grazing conditions. Pasture analyses revealed declining crude protein and increasing fibre (NDF) from early to late lactation, suggesting seasonal nutritional constraints. In combination with interview data, these findings highlight key challenges, including feed scarcity, climatic stress, and limited management resources, all contributing to high cria mortality. Overall, results indicate that while alpaca systems are well adapted to marginal environments and contribute to the sustainable use of native rangelands, their productivity remains highly sensitive to nutritional and climatic limitations. Strengthening feed availability and management practices is therefore critical to enhance resilience, improve animal performance, and support the multifunctionality of Andean agro-ecosystems under changing climatic conditions.

Keywords: Alpaca milk, Andean agro-ecosystems, climate resilience, lactation stage, native pasture