Effects of Different Physical Forms of Starter Feed on Growth Performance, Rumen Fermentation, and Blood Parameters in Calves: Postprint

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Abstract

This study was conducted under hot and humid conditions to investigate the effects of feeding starter feeds with different physical forms on growth and development, rumen fermentation parameters, and blood parameters of calves. Thirty-six Holstein heifer calves were randomly assigned to 3 groups (n=12 per group) and offered ad libitum access to pelleted starter feed (PSA), powdered starter feed (PSB), or textured starter feed (TS). The experimental period lasted 63 days, with days 1-42 as the pre-weaning period (normal milk feeding period), days 43-49 as the weaning period, and days 50-63 as the post-weaning period. Blood sampling and body weighing were performed before morning feeding on days 1, 42, 49, and 63, and rumen fluid was collected via stomach tube before morning feeding on days 49 and 63. Feed intake and temperature-humidity index were recorded daily throughout the trial. The results showed that under hot and humid conditions: 1) During the weaning period and the subsequent two weeks, the TS group exhibited higher starter feed dry matter intake, average daily gain, and feed conversion ratio compared to the PSA and PSB groups, with the PSB group showing the lowest values, though the differences were not significant ($P>0.05$). 2) Calves in the TS group initiated rumination 3.8 days earlier than those in the PSA group and 4.7 days earlier than those in the PSB group, with both differences being significant ($P<0.05$). On day 63, the TS group had significantly lower rumen fluid ammonia nitrogen concentration than the PSA group ($P<0.05$). 3) On day 42, the PSA group exhibited significantly higher blood immunoglobulin G concentration than the TS group ($P<0.05$). 4) The TS group experienced first diarrhea onset 0.44 days and 1.75 days later than the PSA and PSB groups, respectively, though these differences were not statistically significant ($P>0.05$), and the TS group had the lowest diarrhea incidence. In conclusion, under hot and humid conditions, textured starter feed better promoted calf growth and development, facilitated earlier initiation of

rumination behavior, and promoted rumen function development compared to pelleted and powdered starter feeds.

Full Text

Effects of Starters in Different Physical Forms on Growth and Development, Rumen Fermentation and Blood Parameters of Dairy Calves

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Abstract: This study investigated the effects of feeding starters with different physical forms on growth performance, rumen fermentation parameters, and blood indices of dairy calves under hygrothermal conditions. Thirty-six Holstein heifer calves were randomly assigned to three groups (n=12 per group) and offered ad libitum access to pelleted starter (PSA), powdered starter (PSB), or texturized starter (TS). The 63-day trial consisted of a pre-weaning period (Days 1–42) with normal milk feeding, a weaning period (Days 43–49), and a post-weaning period (Days 50–63). Blood samples and body weights were collected before morning feeding on Days 1, 42, 49, and 63, while rumen fluid was sampled via gastric tube on Days 49 and 63. Feed intake and temperature-humidity index (THI) were recorded daily.

The results indicated that under hygrothermal conditions: (1) During the weaning period and the subsequent two weeks, TS group exhibited higher starter dry matter intake, average daily gain, and gain-to-feed ratio compared with PSA and PSB groups, with PSB showing the lowest values, though differences were not significant ($P>0.05$). (2) Calves in TS group initiated rumination 3.8 days earlier than PSA group and 4.7 days earlier than PSB group ($P<0.05$). At 63 days of age, TS group had significantly lower ruminal ammonia nitrogen content than PSA group ($P<0.05$). (3) On Day 42, PSA group showed significantly higher serum immunoglobulin G concentration than TS group ($P<0.05$). (4) The initial diarrhea occurrence in TS group was delayed by 0.44 and 1.75 days compared with PSA and PSB groups, respectively, without statistical significance ($P>0.05$), and TS group demonstrated the lowest diarrhea rate. In conclusion, under hygrothermal conditions, texturized starter more effectively promoted calf growth and development, facilitated earlier rumination behavior, and contributed to improved rumen function compared with pelleted and powdered starters.

Keywords: calves; starter; rumination behavior; intake; temperature-humidity index; rumen fermentation

Introduction

Dairy calves represent critical replacement stock that profoundly influences the long-term sustainability of dairy operations, making calf rearing management a paramount concern for producers. Ensuring rapid and healthy growth during early life carries significant economic importance. The first three months of life constitute a transitional phase from liquid feed (milk) to solid feed and coincide with rapid rumen development [1]. Calves aged 2–3 weeks frequently experience diarrhea due to declining passive immunity, while rumination behavior typically emerges around one month of age, marking a crucial milestone in rumen development [2]. Starter feed serves as the primary stimulus for rumen development during this period [3-4].

Numerous studies have investigated how chemical composition of starters affects calf growth. Stamey et al. [5] reported that feeding 28% crude protein milk replacer significantly increased 8-week body weight compared with 20% protein replacer. Santos et al. [6] demonstrated that essential oils in starter could substitute for antibiotics. Zhang et al. [7] found that maintaining plant protein below 50% in milk replacer facilitated healthy transition from maternal milk. However, research on physical form effects remains limited. Bateman et al. [8] observed that high powder content in starter reduced intake and daily gain. Recent evidence indicates that alfalfa hay particle length in starter correlates with rumen wall development, with 12.5% inclusion at 3 mm length enhancing calf performance [9], shifting research focus toward optimizing starter physical form.

Bach et al. [10] found texturized starter increased intake compared with pelleted starter, while Moeini et al. [11] reported both powdered and texturized starters promoted intake versus pelleted feed, with texturized showing highest feed conversion efficiency. These findings underscore the importance of physical form. Environmental temperature and humidity also substantially impact calf development. Tao et al. [12] documented adverse effects of heat stress on newborn calves, increasing mortality and reducing dry matter intake. Hill et al. [13] demonstrated that cooling measures for calf hutches significantly improved body weight gain during summer. In many Chinese regions, high summer THI impairs normal feeding and can cause heat stress or mortality.

Given limited data on physical form effects under hygrothermal conditions, this study investigated how different starter physical forms influence calf growth, rumen fermentation, and blood parameters during summer, aiming to provide data supporting starter application and development in calf management.

Materials and Methods

Experimental Starters

Three experimental starters with identical formulation but different physical forms were provided by Beijing Zhengda Feed Technology Co., Ltd.:

1. **Pelleted starter (PSA):** Conventional pellet processing; 4.5 mm diameter; pellet durability index (PDI) 90.8%
2. **Powdered starter (PSB):** Produced by grinding and mixing raw ingredients
3. **Texturized starter (TS):** Concentrated pellets coarsely mixed with other ingredients and sprayed with molasses; corn processed to >80% retention on 8-mesh screen, other materials unprocessed

Experimental Design

This study employed a completely randomized design with starter physical form as the treatment factor. Three groups (PSA, PSB, TS) were established accordingly.

Animals and Diets

The trial was conducted at Beijing Zhongdi Animal Husbandry Technology Co., Ltd. in Shunyi District, Beijing. Thirty-six Holstein heifer calves with similar initial body weight [(40.50±2.64) kg] were randomly allocated to three groups (n=12) and fed the respective starters. All calves received 4 L colostrum within 1 h after birth and were housed in individual hutches. The 63-day trial comprised: Days 1–42 (pre-weaning) with milk feeding, Days 43–49 (weaning period) with gradual milk reduction, and Days 50–63 (post-weaning) with starter only. Milk feeding regimen: Days 1–7, 2 L twice daily; Days 15–42, 3 L twice daily; Days 43–49, 2 L twice daily with weaning on Day 49. Starter was offered ad libitum from Day 5. Water was freely available throughout. Calves were dehorned on Day 35. Starter composition and nutrient levels are presented in , and physical forms are shown in [Figure 1: see original paper].

Measurements

Temperature-Humidity Index (THI) Automatic temperature-humidity recorders (DSR-TH, Zoglab Microsystem, Hangzhou) were installed in three randomly selected calf pens among the 36 available, recording every 15 minutes (96 data sets daily). THI was calculated using the formula: THI = [0.8 × ambient temperature (°C)] + {[relative humidity (%)/100] × [ambient temperature (°C) - 14.4]} + 46.4 [14].

Growth Performance Body weight was measured before morning feeding on Days 1, 42, 49, and 63. Starter feed offered and refused was recorded daily to calculate starter dry matter intake. Milk dry matter intake was recorded

to calculate gain-to-feed ratio using the formula: Gain-to-feed ratio = average daily gain / (milk dry matter intake + starter dry matter intake).

Rumen Fluid Collection and Analysis Rumen fluid was collected via gastric tube before morning feeding on Days 42, 49, and 63. pH was measured immediately, then samples were filtered through four layers of sterile gauze, aliquoted into 2 mL tubes, and stored at -20 °C for volatile fatty acid (VFA) and ammonia nitrogen (NH3-N) analysis [15-16].

Blood Sample Collection and Analysis Blood samples (20 mL) were collected via jugular venipuncture before morning feeding on Days 1, 42, 49, and 63. Serum was harvested after centrifugation at 3,000×g for 10 min, aliquoted into 2 mL tubes, and stored at -20 °C. Serum samples were analyzed at the Biochemistry Laboratory of Haidian Hospital using an Olympus Au-600 automatic biochemical analyzer (Japan).

Rumination Behavior Observation Following Hosseini et al. [17], direct observation was conducted for 1 h (07:30–08:30) immediately after morning starter feeding to record rumination behavior.

Diarrhea Recording Calves were observed at 07:00 and 15:00 daily. Diarrhea was scored using a 5-point scale [18]; scores 3 were recorded as diarrhea events. Diarrhea rate was calculated as: Diarrhea rate (%) = 100 × [diarrhea events / (number of calves × trial days)].

Statistical Analysis

Data are presented as means with standard errors. Repeated measures data were analyzed using the MIXED procedure in SAS 9.4. Significance was declared at $P<0.05$. The statistical model was:

$$Yijk = \quad + Ti + Wj + TWij + C(T)ik + \ ijk$$

where T represents treatment (i=1,2,3) as a fixed effect; W represents week of age (j=1,2,3···9) as a fixed effect; C represents calf (k=1,2,3···25) as a random effect; and represents residual error [19].

Results and Analysis

Hygrothermal Environment

As shown in [Figure 2: see original paper], the trial spanned 82 days from first to last calf enrollment, with each calf undergoing a 63-day experimental period. The daily average THI exceeded 72 for 61.0% of the trial days, while daily maximum THI surpassed 72 on 96.3% of days. Given that THI 72 indicates

heat stress in adult cattle [20] and calves exhibited symptoms such as milk refusal and difficulty standing (alleviated by shade), the trial environment was classified as hygrothermal.

Growth Performance

During the pre-weaning period (Days 1–42), no significant differences were observed among groups in starter intake, average daily gain, or gain-to-feed ratio ($P>0.05$) (). During weaning (Days 43–49) and post-weaning (Days 50–63), TS group showed numerically higher starter dry matter intake, average daily gain, and gain-to-feed ratio than PSA and PSB groups, with PSB having the lowest values, though differences remained non-significant ($P>0.05$). Across the entire trial, TS group maintained numerically higher average daily gain and gain-to-feed ratio, while PSB had the lowest average daily gain ($P>0.05$).

Rumen Fermentation Parameters

TS group initiated rumination significantly earlier than PSA and PSB groups ($P<0.05$), by 3.8 and 4.7 days, respectively (). Rumen fluid pH did not differ among groups at 49 or 63 days of age ($P>0.05$). Ammonia nitrogen content was similar among groups at 49 days, but at 63 days, PSA group had significantly higher ammonia nitrogen than TS group ($P<0.05$). Total VFA concentration showed a PSA < PSB < TS pattern at 49 days, but reversed to PSA > PSB > TS at 63 days, without significant differences ($P>0.05$). At 49 days, PSB group had numerically higher butyrate and isobutyrate concentrations than PSA and TS groups, but differences were not significant ($P>0.05$).

Blood Parameters

Serum glucose concentration was highest at 1 day of age and remained stable thereafter at 42, 49, and 63 days (). On Day 42, PSA group exhibited significantly higher immunoglobulin G (IgG) concentration than TS group ($P<0.05$). No significant differences were detected among groups in growth hormone or insulin concentrations throughout the trial ($P>0.05$).

Diarrhea Occurrence

As shown in [Figure 3: see original paper], PSA group exhibited the most concentrated distribution of diarrhea events. TS group showed diarrhea symptoms in only two calves at 40 and 59 days of age. TS group delayed initial diarrhea by 0.44 and 1.75 days compared with PSA and PSB groups, respectively, without statistical significance ($P>0.05$) (). TS group demonstrated the lowest diarrhea rate, though differences among groups were not significant ($P>0.05$).

Discussion

The pre-weaning similarity in starter intake, average daily gain, and gain-to-feed ratio across groups reflects that milk, provided at fixed quantities, was the primary energy source with minimal starter consumption. During weaning, reduced milk allowance forced rapid increases in starter intake, showing a TS > PSA > PSB pattern, though non-significantly. Post-weaning, while PSA group consumed more starter than TS and PSB groups, TS group achieved higher gain-to-feed ratio, suggesting texturized starter better suited post-weaning development. This may be attributed to larger corn particles and whole oats in TS promoting rumination and rumen function development, enabling more efficient feed utilization.

Rumination behavior indicates functional rumen development. TS group' s earlier rumination onset demonstrates its superior stimulation of rumen development. Rumen wall keratinization is enhanced by mechanical friction from textured feed particles, while fermentation of early-consumed concentrates and forages produces VFAs that promote rumen papillae development [21], collectively improving rumen function. Rumen pH values remained within normal ranges. PSB group showed greater pH reduction post-weaning, likely because low starter proportion pre-weaning caused abrupt fermentation increases when starter intake rose, producing more organic acids. Higher ammonia nitrogen in TS group at 42 days may reflect better-developed rumen microbiota and nitrogen utilization efficiency, consistent with higher gain-to-feed ratio.

IgG plays a crucial role in humoral immunity. The lower IgG concentration in TS group at 42 days may be attributed to molasses coating attracting more flies, whose transmitted bacteria or toxins could bind and consume IgG, masking potential growth-promoting effects.

Diarrhea significantly impacts calf development. In this trial, diarrhea occurred predominantly at 3 weeks of age, affecting 34 of 36 calves, suggesting it is a nearly universal challenge during early rumen development when fermentation conditions and regulatory functions are immature. PSB group entered the diarrhea phase 1.75 days earlier than TS group, possibly because powder form caused feed adhesion in the mouth and digestive tract, potentially impairing esophageal groove closure and causing abnormal fermentation [22]. TS group concluded diarrhea approximately 3 days earlier than PSB group, likely because coarsely ground corn and whole oats better accommodated early rumen development. The two diarrhea cases in TS group at 40 and 59 days may represent non-nutritional diarrhea caused by fly-borne pathogens attracted to molasses coating, whereas PSA and PSB groups had more uniformly mixed molasses with no visible surface coating, attracting fewer flies.

In conclusion, under hygrothermal conditions, texturized starter more effectively promoted calf growth and development, stimulated earlier rumination, and enhanced rumen function compared with pelleted and powdered starters.

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Note: Figure translations are in progress. See original paper for figures.