Bovine Colostrum from Simmental Cows: Compositional Analysis and Anti-Carcinogenic Potential

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ABSTRACT

Bovine colostrum, the initial mammary secretion post-calving, is rich in bioactive compounds with potential anti-carcinogenic properties. This study analyzed colostrum from Simmental cows in Kazakhstan over the first postpartum week to characterize its nutritional and bioactive profile, focusing on components relevant to cancer prevention and therapy. Colostrum samples, collected from five cows at 3, 6, and 12 hours post-calving and daily thereafter for 168 hours, were analyzed for proximate composition, vitamins, minerals, and toxic elements. Total solids and protein, including immunologically active proteins like lactoferrin and proline-rich polypeptides, peaked at 3 hours (~25% and 15%, respectively) and declined sharply within 24–36 hours. Fat and lactose showed moderate and minimal changes, respectively. Antioxidant vitamins (E: 3.75 mg/kg; C: 2.80 mg/100g) and minerals (Ca: 831.5 mg/kg; P: 687.5 mg/kg) support redox and immune functions, while the absence of toxic elements (Pb, Cd, As, Hg) confirms safety. These findings highlight colostrum's potential as a source of anti-carcinogenic compounds, particularly lactoferrin and proline-rich polypeptides, which may modulate immune responses and inhibit tumor growth. Early harvesting (<24 hours) is critical to maximize bioactive yield for potential nutraceutical applications in cancer prevention..

KEYWORDS: Bovine Colostrum, Simmental Cows, Lactoferrin, Proline-Rich Polypeptides, Anti-Carcinogenic Properties, Nutraceuticals

INTRODUCTION

Bovine colostrum, the initial mammary secretion produced within the first few days post-calving, is a nutrient-dense fluid rich in bioactive compounds with significant potential for cancer prevention and adjunctive therapy [1,2,3]. Unlike mature milk, colostrum contains elevated concentrations of immunoglobulins, lactoferrin, proline-rich polypeptides (PRPs), growth factors, cytokines, and antioxidants, which collectively contribute to its immunomodulatory, anti-inflammatory, and anti-carcinogenic properties [4,5,6]. Lactoferrin, an 80-kDa iron-binding glycoprotein, is a cornerstone of colostrum's therapeutic potential, exhibiting anti-tumor effects through multiple mechanisms. It inhibits cancer cell proliferation, induces apoptosis, and suppresses angiogenesis by modulating key signaling pathways, including NF-κB, p53, and PI3K/Akt, as demonstrated in preclinical models of colorectal, breast, and lung cancers [3,7,8,9]. Lactoferrin also sequesters iron, a critical nutrient for tumor growth, thereby limiting cancer cell viability [10,11]. Proline-rich polypeptides enhance immune surveillance by stimulating T-cell differentiation, natural killer (NK) cell activity, and cytokine production, which may suppress tumor growth and metastasis, particularly in gastrointestinal malignancies [3,12,13]. These immunomodulatory effects are complemented by colostrum's antioxidant components, including vitamins A, E, and C, which mitigate oxidative stress—a key driver of DNA damage and carcinogenesis [5,14,15]. Selenium, a trace element present in colostrum, further enhances its anti-carcinogenic potential by activating glutathione peroxidase, an enzyme that neutralizes reactive oxygen species (ROS) implicated in cancer progression [5,16]. The synergistic interplay of these bioactive molecules positions colostrum as a promising nutraceutical for preventing inflammation-driven cancers, such as those of the gastrointestinal tract, where chronic inflammation is a well-established risk factor [2,17,18]. In Kazakhstan, Simmental cow colostrum represents an abundant yet underutilized resource for developing oncology-focused nutraceuticals [19,20]. The Simmental breed, valued for its dual-purpose dairy and beef production, produces colostrum with a unique compositional profile influenced by regional factors such as genetics, feed composition, and environmental conditions

[1,21]. Studies suggest that colostrum composition varies significantly across breeds and regions, necessitating localized investigations to optimize its therapeutic applications [10,22]. Preliminary research at S. Seifullin Kazakh Agrotechnical Research University indicates that Simmental colostrum is particularly rich in proteins (e.g., lactoferrin, immunoglobulins) and antioxidants during the first 24 hours post-calving, a critical window for capturing peak bioactive concentrations [23,24]. This high initial protein content, which declines rapidly within 24–36 hours, underscores the importance of early harvesting to maximize anti-carcinogenic potential [19,25]. For instance, lactoferrin and PRPs, which are most abundant immediately post-calving, are sensitive to degradation and require timely collection to ensure efficacy in nutraceutical formulations [6,24]. Preservation techniques, such as lyophilization, can stabilize these bioactive compounds, enabling their incorporation into functional foods or dietary supplements for cancer prevention [20,25]. However, challenges remain, including variability in colostrum composition due to regional farming practices, inconsistent feeding regimens, and environmental factors like soil selenium content, which may affect trace element levels [1,17]. Moreover, the lack of standardized processing protocols and clinical data on colostrum's anti-carcinogenic efficacy in humans limits its immediate application [2,22]. Addressing these gaps requires comprehensive compositional studies and rigorous clinical validation to establish colostrum as a viable nutraceutical for oncology [10,12].

This study characterizes the compositional dynamics of Simmental cow colostrum in Kazakhstan over the first postpartum week, with a focus on lactoferrin, PRPs, antioxidants (vitamins A, E, C), and trace elements like selenium. By elucidating the temporal changes in these cancer-relevant components, we aim to provide a foundation for developing colostrum-based nutraceuticals tailored for cancer prevention, particularly for gastrointestinal malignancies. Leveraging Kazakhstan's abundant dairy resources, this research seeks to bridge the gap between regional colostrum production and global health applications, offering insights into optimizing bioactive yield and ensuring safety for therapeutic use.

MATERIALS AND METHODS

2.1. Sample Collection
Colostrum was collected from five healthy Simmental cows at a dairy farm in Kazakhstan, with each cow yielding 1.5–2.0 L per milking. To ensure ethical calf nutrition, 50% of colostrum was reserved for calves, and 50% was used for analysis. Samples were collected at 3, 6, and 12 hours post-calving, three times on day 2, and daily thereafter for 7 days (168 hours). Pooled samples were stored at -20°C until analysis to preserve bioactive compounds, including lactoferrin and proline-rich polypeptides.

2.2. Proximate Composition Analysis
The nutritional profile, focusing on total solids, protein, and fat, was determined using AOAC International (2019) standard methods [8]. Protein content, including immunologically active components like lactoferrin, was quantified to assess anti-carcinogenic potential. Analyses were conducted in triplicate to ensure accuracy.

2.3. Determination of Titratable Acidity and pH
Titratable acidity (TA) was measured by titration with 0.1 mol NaOH to the phenolphthalein endpoint, expressed in Turner degrees (°T) [9]. Active acidity (pH) was determined potentiometrically using a calibrated glass electrode pH meter [9]. These measurements assessed colostrum's stability, critical for preserving bioactive compounds.

2.4. Vitamin Analysis
Fat-soluble vitamins (A, E) and water-soluble vitamins (B1, B2, B3, B6, B12, C) were quantified using high-performance liquid chromatography with UV detection (HPLC-UV) [10]. Vitamin C, an antioxidant relevant to cancer prevention, was measured via colorimetric titration with 2,6-dichlorophenolindophenol [11]. All measurements were performed in triplicate.

2.5. Mineral Analysis
Mineral content, including calcium (Ca), phosphorus (P), magnesium (Mg), iron (Fe), and selenium (Se), was determined using flame atomic absorption spectrometry (FAAS) with certified reference materials for validation [12]. Selenium, linked to anti-carcinogenic properties, was a key focus. Triplicate measurements ensured precision [5].

2.6. Toxic Elements Analysis
Lead (Pb), cadmium (Cd), arsenic (As), and mercury (Hg) were quantified using inductively coupled plasma mass spectrometry (ICP-MS) after microwave digestion in nitric acid, following EPA SW-846 Method 6020B [13]. Calibration used multi-point external standards with internal standard correction, ensuring compliance with EN 15763:2009 and AOAC 2015.01 [14,15]. Non-detection of toxic elements confirmed colostrum safety for nutraceutical applications.

2.7. Statistical Analysis
All measurements were conducted in triplicate (n=3), with results reported as means ± standard deviation. Data reliability was ensured using ANOVA and Tukey's test for significant differences ($p < 0.05$). Outlier tests were applied to validate consistency.

RESULTS

3.1. Compositional Dynamics
Titratable acidity of Simmental cow colostrum decreased exponentially from 58 ± 2 °T at 3 hours post-calving to 24 ± 1 °T by 168 hours, while pH increased logarithmically from 4.92 ± 0.05 to 6.65 ± 0.03 by 72 hours (Figure 1). These changes reflect reduced buffering capacity, critical for preserving bioactive proteins with anti-carcinogenic potential [9].
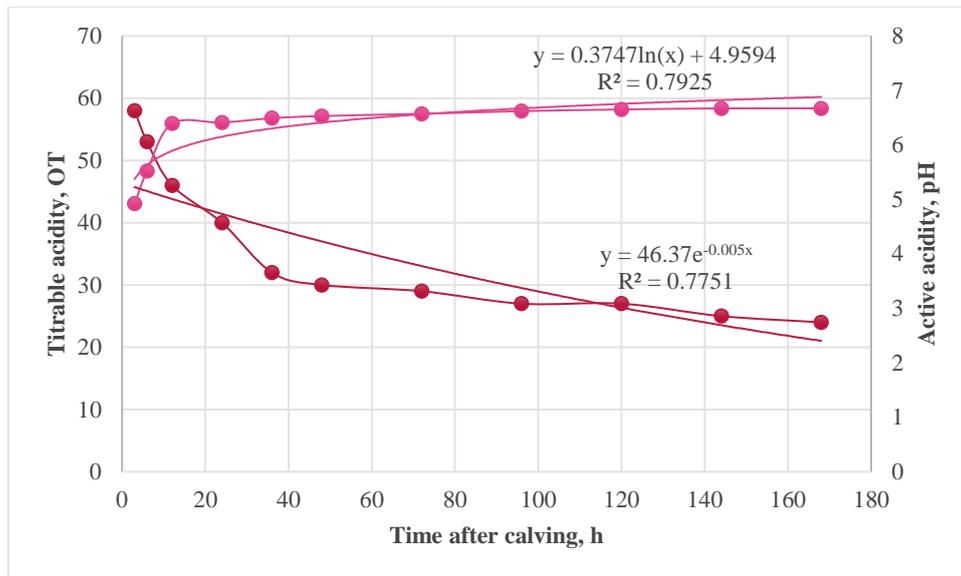
$$y = 0.3747\ln(x) + 4.9594$$
$$R^2 = 0.7925$$

$$y = 46.37e^{-0.005x}$$
$$R^2 = 0.7751$$

Figure 1. Dynamics of colostrum acidity during the first week post-calving.

3.2. Chemical Profile

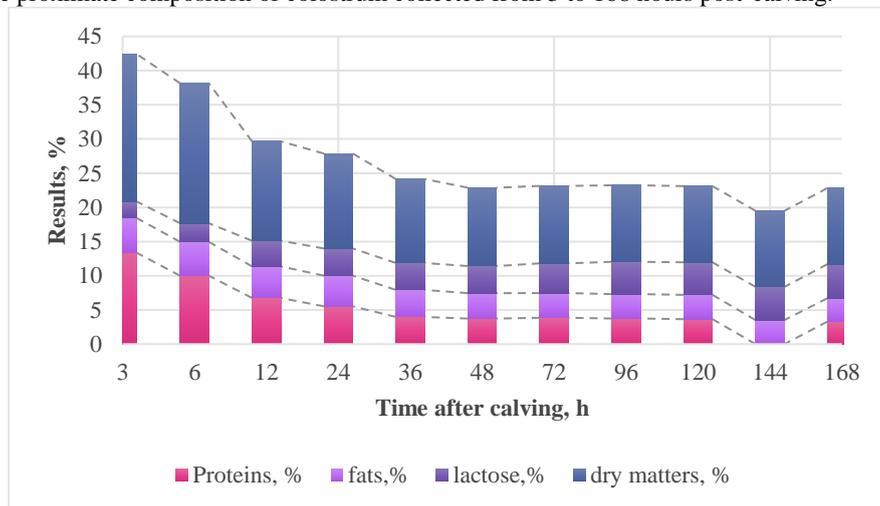Figure 2 presents the proximate composition of colostrum collected from 3 to 168 hours post-calving.

Figure 2. Proximate composition of colostrum.

The chemical composition of colostrum, analyzed from 3 to 168 hours post-calving, showed a rapid transition in cancer-relevant components (Figure 2). Total solids declined from $25.0 \pm 1.2\%$ at 3 hours to $12.5 \pm 0.6\%$ by 36 hours, driven by a sharp decrease in protein content ($15.0 \pm 0.8\%$ to $4.0 \pm 0.3\%$), including lactoferrin and proline-rich polypeptides, key for immunomodulatory and anti-carcinogenic effects [19]. Fat content decreased moderately from $6.0 \pm 0.4\%$ to $3.5 \pm 0.2\%$ within 24 hours and stabilized thereafter. Lactose increased slightly from $3.0 \pm 0.2\%$ to $4.5 \pm 0.2\%$ by 36 hours, consistent with lactogenesis onset [23].

3.3. Vitamin Content

The vitamin profile (Table 1) underscored colostrum's antioxidant capacity. Vitamin E (3.75 ± 0.10 mg/kg) predominated among fat-soluble vitamins, followed by vitamin A (1.13 ± 0.05 mg/kg), supporting redox protection against carcinogenesis [21]. Water-soluble vitamins included niacin (B3, 7.12 ± 0.80 mg/100g), pantothenic acid (B5, 2.10 ± 0.10 mg/100g), riboflavin (B2, 1.61 ± 0.50 mg/100g), and vitamin C (2.80 ± 0.01 mg/100g), a key antioxidant [11]. Variability in B2 and B3 suggests biological heterogeneity, potentially influencing anti-carcinogenic efficacy [10].

Table 1. Proximate composition of vitamins, minerals and toxic elements in colostrum.

Parameters	Dry colostrum
Vitamins	
A, mg/kg	1.13 ± 0.01
E, mg/kg	3.75 ± 0.01
B_1 mg/100g	0.23 ± 0.01
B_2 mg/100g	1.61 ± 0.5
B_3 mg/100g	7.12 ± 0.8
B_5 mg/100g	2.1 ± 0.1

B$_6$,mg/100g	0.3±0.01
C, mg/100g	2.8±0.01
Minerals	
Fe	0.4±0.01
Mg	53.0±0.1
Ca	831.5±6.1
P	687.5±8.9
Se	0.05±0.01
Toxic elements	
Pb,	nd
Cd	nd
As	nd
Hg	nd

nd- not defined.

3.4. Mineral Content

Mineral analysis (Table 1) revealed high calcium (831.5 ± 6.1 mg/kg) and phosphorus (687.5 ± 8.9 mg/kg), with a Ca:P ratio of 1.21 ± 0.02, supporting immune and enzymatic functions. Selenium (0.05 ± 0.01 mg/kg), a trace element with anti-carcinogenic properties, was detected at low but consistent levels [5]. Low variability indicated analytical precision [12].

3.5. Toxic Elements Content of Colostrum

No detectable levels of lead (Pb), cadmium (Cd), arsenic (As), or mercury (Hg) were found using ICP-MS (limits of detection: Pb <0.01 mg/kg, Cd <0.005 mg/kg, As <0.01 mg/kg, Hg <0.002 mg/kg), confirming colostrum's safety for nutraceutical applications in cancer prevention [16].

DISSCUSION

The rapid decline in protein content (15.0 ± 0.8% to 4.0 ± 0.3% within 24–36 hours post-calving), particularly lactoferrin and proline-rich polypeptides, underscores the critical need for early colostrum harvesting to capture peak concentrations of anti-carcinogenic compounds [1,19,23]. Lactoferrin, an iron-binding glycoprotein, inhibits tumor cell proliferation and induces apoptosis via pathways such as NF-κB and p53, while proline-rich polypeptides enhance immune surveillance by stimulating T-cell and natural killer cell activity, potentially suppressing tumor growth and metastasis [3,4,7]. These findings align with studies demonstrating bovine colostrum's immunomodulatory and anti-carcinogenic effects, particularly in gastrointestinal cancers [2,6,22]. The high initial protein richness in Kazakh Simmental colostrum (15.0 ± 0.8% at 3 hours) highlights its potential as a nutraceutical ingredient for cancer prevention, but the sharp decline emphasizes the importance of sampling within 24 hours post-calving [17,24,26].

The antioxidant profile, dominated by vitamin E (3.75 ± 0.10 mg/kg), vitamin C (2.80 ± 0.01 mg/100g), and niacin (7.12 ± 0.80 mg/100g), supports colostrum's role in mitigating oxidative stress, a key driver of carcinogenesis [6,11,21]. These antioxidants, combined with trace selenium (0.05 ± 0.01 mg/kg), known for its anti-carcinogenic properties via glutathione peroxidase activation, enhance colostrum's protective effects against cellular damage [5,16]. Variability in B2 and B3 levels (SDs of 0.50 and 0.80 mg/100g) suggests biological heterogeneity, possibly due to regional feed practices in Kazakhstan, which warrants further investigation to optimize antioxidant content for oncological applications [1,10,20]. The dry-basis reporting may inflate concentrations compared to wet colostrum, limiting direct comparisons with literature (e.g., wet-basis vitamin E ~1–2 mg/kg) [7,20,27]. Physical properties, such as the exponential decline in titratable acidity (58 ± 2 °T to 24 ± 1 °T), further influence the stability of bioactive compounds, critical for their therapeutic efficacy [9,26].

The absence of detectable toxic elements (Pb, Cd, As, Hg; LODs <0.01–0.002 mg/kg) confirms the safety of Kazakh Simmental colostrum for nutraceutical use, surpassing EU thresholds (e.g., Pb <0.020 mg/kg) [16]. However, the small sample size (n=5) and lack of source tracking (e.g., soil, feed) may underestimate risks in potentially polluted regions, necessitating broader monitoring [17,18]. Limitations include the small sample size and pooled sampling, which may mask individual cow variability, and the absence of specific quantification of lactoferrin and proline-rich polypeptides [24,27]. Future studies should employ proteomics to track these compounds' dynamics, assess bioavailability post-preservation (e.g., lyophilization), and conduct clinical trials to validate anti-carcinogenic efficacy in humans [22,25,28]. These findings position Simmental colostrum as a promising resource for oncology-focused nutraceuticals in Kazakhstan, but region-specific optimization and standardization are needed to maximize its therapeutic potential.

CONCLUSIONS

This study highlights the potential of Simmental cow colostrum in Kazakhstan as a rich source of anti-carcinogenic compounds for cancer prevention. The rapid decline in protein content, including lactoferrin and proline-rich polypeptides (15.0 ± 0.8% to 4.0 ± 0.3% within 24–36 hours post-calving), underscores the need for early harvesting within 24 hours to maximize these immunomodulatory and tumor-suppressive components. The antioxidant-rich vitamin profile, with high levels of vitamin E (3.75 ± 0.10 mg/kg), vitamin C (2.80 ± 0.01 mg/100g), and niacin (7.12 ± 0.80 mg/100g), supports protection against oxidative stress, a critical factor in carcinogenesis. Trace selenium (0.05 ± 0.01 mg/kg) further enhances colostrum's anti-carcinogenic potential through enzymatic activity. The absence of toxic elements confirms its safety for nutraceutical applications. Despite limitations such as small sample size and lack of specific quantification of lactoferrin and proline-rich polypeptides, these findings position

Simmental colostrum as a promising resource for developing nutraceuticals, particularly for preventing gastrointestinal cancers. Future research should focus on proteomic analysis to quantify anti-carcinogenic compounds, assess bioavailability post-preservation, and conduct clinical trials to validate efficacy in human cancer prevention, leveraging Kazakhstan's dairy resources for global health applications.

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