BMC Veterinary Research

RESEARCH Open Access

Cumulative incidence of ketosis in fresh lactating cows: a case study in the United Arab Emirates

Gobena Ameni[1,2*], Shaikha Saif Ali Alshamsi[1], Berecha Bayissa[3], Aboma Zewude[1], Temesgen Mohammed[1], Berhanu Adnew Degefa[4], Mansour Alhemairi[1], Asha Antony[1], Khaja Mohteshamuddin[1], Gopala Kalaiah[5], Mohammed Ali Omer[5], Meera Saeed Alkalbani[6], Yassir Mohammed Eltahir[6], Mohamed Elfatih Hamad[4], Ihab Habib[1], Teshale Sori[7] and Markos Tibbo[8]

Abstract
Non-infectious diseases such as ketosis could present a major threat to the development of the dairy subsector in the United Arab Emirates (UAE). A retrospective study (2019 to 2022) was conducted on 7511 fresh lactating cows to estimate the monthly cumulative incidences of subclinical ketosis (SCK) and clinical ketosis (CK) at one dairy farm in the UAE as a case study. Clinical examination for signs of ketosis and measuring the blood β-hydroxybutyrate (BHB) concentration were used for defining the ketosis status of the study cows. Repeated measures analysis of variance (ANOVA) and binary logistic regression analyses were used for data analysis. The mean monthly cumulative incidence of SCK over four years was 11.16% (95% CI: 10.45, 11.89) while that of CK was 0.53% (95% CI: 0.38, 0.72). The mean monthly cumulative incidences of both SCK was associated ($p < 0.0001$) with year, season and parity. Besides, the mean monthly cumulative incidence of CK was associated year ($p < 0.01$) with season. Thus, the mean monthly cumulative incidence of CK was low at the study farm while that of SCK was moderate. Therefore, control and preventive measures of ketosis were recommended to reduce the incidence of SCK at the study farm.

Keywords Cumulative incidence, Clinical ketosis, Fresh lactating cows, Subclinical ketosis

*Correspondence:
Gobena Ameni
gobena.ameni@uaeu.ac.aeand; gobena.ameni@aau.edu.et
[1]Department of Veterinary Medicine, College of Food and Agriculture, United Arab Emirates University, Al Ain, United Arab Emirates
[2]Aklilu Lemma Institute of Pathobiology, Addis Ababa University, Addis Ababa, Ethiopia
[3]Vaccine Production and Drug Formulation Directorate, National Veterinary Institute, Bishoftu, Ethiopia
[4]Department of Integrative Agriculture, College of Food and Agriculture, United Arab Emirates University, Al Ain, United Arab Emirates
[5]National Dairy Farm, Al Ain, United Arab Emirates
[6]Animal Health Division, Abu Dhabi Agriculture and Food Safety Authority, Abu Dhabi, United Arab Emirates
[7]Department of Clinical Studies, College of Veterinary Medicine and Agriculture, Addis Ababa University, Bishoftu, Ethiopia
[8]Subregional Office for the Gulf-Cooperation Council States and Yemen, Food and Agriculture Organization of the United Nations, Abu Dhabi, United Arab Emirates

Introduction

Ketosis (hyperketonemia) is a metabolic disease of dairy cows that occurs as a result of an imbalance between energy requirements for milk production and energy intake [1]. The negative energy balance leads to excessive mobilization of adipose reserves, which results in the accumulation of non-esterified fatty acids and ketone bodies (acetone, acetoacetate, and BHB) in the blood [1]. Furthermore, recent studies on the metabolome profile of dairy cows and water buffalo during early lactation indicated that in addition to excessive lipomobilization, ketosis can also result from a lack of amino acids and vitamins [2, 3]. BHB is the most dominant and more stable ketone body in the cow's blood and is hence used for the diagnosis of hyperketonemia in dairy cows [4, 5]. Depending on the severity of the negative energy imbalance and concentration of ketone bodies in the blood, ketosis can be either subclinical or clinical mainly depending on the presence or absence of clinical signs of ketosis. In addition, cows having < 1.2 mmol/L BHB in their blood are considered negative for ketosis; cows in which a blood concentration of BHB ranging from 1.2 to 2.99 mmol/L are considered to have subclinical ketosis; whereas those cows with a blood concentration of BHB ≥ 3 mmol/L are regarded as having clinical ketosis [4, 6]. In addition to increase in the concentration of BHB, changes in the concentrations of 13 other metabolites that are related to mobilization body reserves, lipids, amino acids, carbohydrate metabolism and ruminal fermentation were observed in ketotic early lactating cows [2]. However, none of these metabolites has been optimized for clinical application so far.

Several studies indicated that increased concentration of BHB or non-esterified fatty acids in the blood of dairy cows is associated with an increased risk of developing various diseases, reproductive disorders, and changes in milk production [5–7]. Subclinical ketosis has been shown to be associated with metritis, cystic ovarian disease, and displaced abomasum and also leads to clinical ketosis [7]. Furthermore, it was reported that a higher concentration of BHB two weeks after calving is associated with a decreased conception and an increased culling rate [5, 8, 9]. Besides, another group of researchers [10] indicated that an increase in the concentration of BHB in the blood after calving is associated with a considerable drop in milk yield. Interestingly, in vitro studies demonstrated that ketone bodies have a direct effect on the neutrophils suggesting the possibility of ketosis to increase the risk of infectious diseases such as metritis and mastitis in dairy cows [11, 12].

The UAE Government has set a goal to become one of the countries with the best performance in the food security index [13]. To this end, the UAE Government has set a goal to become one of the 10 top countries in the food security index by 2051 [14]. It is believed that dairy production is one of the key contributors to food security in the country, as it serves as a source of fresh milk and dairy products. The growth in demand for dairy products and the market for dairy products in the UAE are attracting investment in the subsector despite the challenges of feed shortage and harsh climatic conditions [15]. Presently, the UAE has a good number of large-scale dairy farms which play important roles as a source of fresh milk and other dairy products [15]. Nonetheless, in connection to dairy expansion, it is expected that metabolic diseases could prevail in dairy farms and negatively affecting the production and productivity of the cows. Among others, ketosis can be considered one of the major metabolic diseases that affect dairy cows with severe economic loss to the dairy sector in the UAE. However, there is a paucity of published data on the epidemiology of ketosis in dairy farms in the UAE. This study was conducted to investigate the epidemiology of ketosis at one dairy farm located in the Al Ain region of the UAE.

Materials and methods

Study farm and its settings

The farm was conducted started operation in 1999 and its current average herd size is 3,800 Holstein Friesian dairy animals, including a milking herd of over 1,450 cows in addition to the dry and replacement stock. The farm is located outside of Al Ain City on the Al Ain—Dubai road. The cows are housed in different horses with cooling systems that keep the house temperature at about 20°C regardless of outside temperature. The cows are milked four times a day for their comfort through a modern facility using best practices and the latest technology including a system of daily monitoring of individual cow somatic cell counts. The farm has installed SaberTM Somatic cell counter (SCC) (registered in New Zealand) that is attached to the milking line. The SCC is monitored by color alerts that are displayed by the counter. All cows with red display (SCC > 800,000 cells/mL of milk) are moved to Medics Pen for treatment and follow up and the bulk tank milk sample is checked for SCC on periodically, and its SCC is kept at < 200,000 cells/mL. In addition, the farm uses its own in-house laboratory to monitor milk quality and herd health status. It operates using Dairycomp 305 Herd Management software and SAP ERP system [16]. Feed is the highest expensive item and the management works with the best global dairy nutritionists to ensure maximum feeding efficiency. Feed is sourced globally depending on quality, pricing, and availability. The milking herd is fed on total mixed ration (TMR) four times a day that is routinely analyzed using near-infra-red (NIR) technology.

Cumulative incidence

Cumulative incidence also termed as risk is one of the epidemiological measures used to quantify disease occurrence. It measures the proportion of non-diseased animals at the beginning of a period of study that becomes diseased during the period [17]. Cumulative incidence is an indication of the average risk of developing disease during a particular period at individual and population level. In this study, the proportion of freshly calved cows which were affected by either form of ketosis at each month of the four study years was used to calculate the cumulative incidence of clinical ketosis or subclinical ketosis. The monthly diagnosed cases were used to calculate cumulative incidence on yearly basis. Since the calving interval of cows is usually about one year the chance of occurrence of ketosis in fresh lactating cows in once per year. Cows which exhibited clinical signs of ketosis such as loss of appetite, drop in milk yield, licking inanimate substances, weight loss and the other signs of ketosis were considered as clinical cases. In addition to clinical signs, clinical cases had blood concentration of BHB $\geq$ 3 mmol/L. On the other hand, cows which did not exhibit clinical signs of ketosis but had high blood concentration of BHB ranging from 1.2 to 2.99 mmol/L were considered as subclinical cases of ketosis [4, 6].

Study cows and extraction of data from records

Retrospective data of all the freshly calved cows ($N = 7511$), recorded from 2019 to 2022 on a daily basis were extracted and used for analyzing cumulative incidences of SCK and CK. Although the herd size of the farm was 3800, 7511 lactating cows were tested for BHB over four years since one cow was tested multiple times at every parturition. Accordingly, the number cows tested in 2019, 2020, 2021 and 2022 were 1699, 1763, 1983 and 2066, respectively. Since all lactating cows were tested every year, almost all the study cows were expected to be tested four times. Testing of ketosis was done once on the 6th day of lactation. All the fresh cows were fed on feed supplemented with propylene glycol (300 g) per cow every day for 6 days post parturition and then tested for ketosis on the 6th day in milk, (DIM). The extraction of data and the analysis were performed at the end of 2022 and the beginning of 2023. During regular herd health monitoring visits every morning for six days, veterinarians of the farm clinically examined these fresh cows for any abnormalities and on the 6th DIM they withdrew blood samples from the coccygeal veins for testing the BHB concentration. The blood concentration of BHB was directly determined on-site using a handheld meter (PrecisionXceed, Abbott Diabetes Care Inc., Alameda, CA) that was previously validated for use in cows [18, 19].The cows were classified based on the standard classification scheme used worldwide. Accordingly, the cow was considered negative when the BHB of a cow was less than 1.2mmol/L of blood. When the blood concentration of BHB was between 1.2 and 2.9mmol/L (both values included), however, the cow was considered positive for SCK while when the blood concentration of BHB was $\geq$ 3.0mmol/L, the cow was considered positive for CK [4, 6]. Clinical signs were also observed occasionally. The recorded clinical signs were loss of appetite, rapid weight loss, licking inanimate objects, salivation, walking in circle, head pushing and others. Unfortunately, the data were generated by the farm as a routine activity of the farm, further testing of the samples with by the gold standard biochemistry analyzer was not done. Figure 1 shows the summary extraction and analysis the data used for this study. The outcomes (dependent variables) were SCK and CK. The potential risk factors (predictors, independent variables) included were study year, season, body condition score, and parity.

Statistical analysis

Mean monthly cumulative incidences of SCK of the four years were compared using repeated measures analysis of variance with Geisser Greenhouse correction. The median and interquartile range (IQR) and the Friedman test (repeated measures non-parametric analysis of variance) was used for the mean monthly cumulative incidence of CK as it could not fulfill the criteria of normality test. Dunn's multiple comparison test was deployed for comparison of the means of monthly cumulative incidences of CK of the four years. The analysis of the association of potential risk factors, predictors (study year, season, body condition score and parity number) with the monthly cumulative incidence of either SCK conducted using IBM SPSS Statistical software version 28.0. As it has been described in the epidemiology reference book [17], odds ratio (OR) can be used to assess the association of risk factors with the incidence of diseases instead of relative risk. In binary logistic regression, all potential risk factors were considered predictors. The likelihood ratio chi-square test was used in testing the association between potential risk factors and the mean monthly cumulative incidence of SCK or CK. Univariable logistic regression analysis was performed to quantify the strength of association by computing the odds ratio for each potential risk factor. Factors which were associated ($p < 0.05$) with the mean monthly cumulative incidence in univariable regression model were retained and considered for multivariable logistic regression analysis. Statistical significance was determined based on $p < 0.05$ or 95% confidence interval.

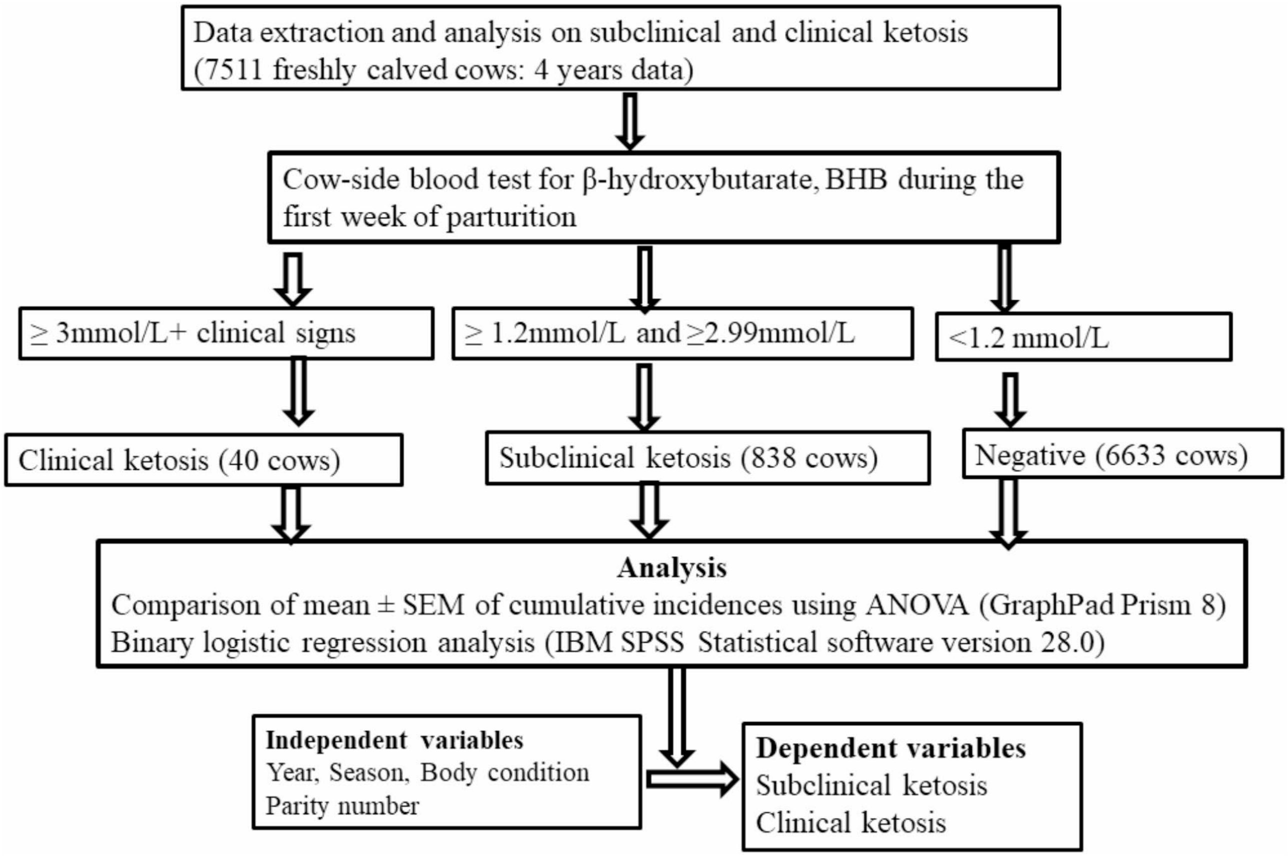

Fig. 1 A flow chart that shows data collection and analysis procedures. A total of 7511 freshly calved cows were tested for BHB and classified into positive for clinical ketosis, subclinical ketosis, or negative for ketosis. Subclinical ketosis and clinical ketosis were considered dependent variables. Year, season, body condition, and parity number were considered as independent variables

Results

Cumulative incidence of subclinical ketosis at the study dairy farm

The mean monthly cumulative incidence of SCK at the study farm over the four years (2019 to 2022) was 11.16% (838/7511; 95% CI: 10.45, 11.89) and it was significantly varied over the years (repeated measures ANOVA with Geisser = Greenhouse correction: $F_{(1.93,\ 21,22)} = 15.91$, $p < 0.001$; Fig. 2A). The mean monthly cumulative incidences (mean ± SEM) of SCK were 0.21 ± 0.018, 0.12 ± 0.025, 0.06 ± 0.012, 0.08 ± 0.013 in 2019, 2020, 2021 and 2022, respectively (Fig. 2A and Table 1). The mean monthly cumulative incidence was showed a progressive increase from parity 1 (7.0 ± 0.48) to parity 5 (21.2 ± 1.6) (Fig. 3B). Out of the total of 838 SCK-positive cows, 88.7% were affected only once i.e. at one parity alone, 10.0% were affected twice (at two different parities) while 1.3% of them were affected three times (at three different parities).

Table 2 presents the results of univariate and multivariable logistic regression analyses of the association of the mean monthly cumulative incidence of SCK with the potential risk factors. Based on a multivariate binary logistic regression analysis, the odds of the mean cumulative incidences of SCK were 2.75 (95% CI: 3.00, 4.70), 2.10 (95% CI: 1.66, 2.66) and 1.33 (95% CI: 1.04, 1.72) times higher in 2019, 2020 and 2022 than the odds of the mean monthly cumulative incidence of SCK in 2021, respectively (Table 2). The odds of the mean cumulative incidence of SCK in winter season was 2.08 (95% CI: 1.71, 2.53) and 1.90 (95% CI: 1.55, 2.32) times higher than that of the autumn season based on the univariate and multivariate binary logistic regression analyses, respectively (Table 2). Furthermore, the odds the mean monthly cumulative incidence of SCK at parities 3, 4, 5, 6 and 7 were 2.30 (95% CI: 1.86, 2.86), 3.19 (95% CI: 2.51, 4.06), 3.49 (95% CI: 2.55, 4.77), 2.63 (95% CI: 1.74, 3.97) and 2.36 (95% CI: 1.43, 3.88) times higher that of parity 1, respectively.

Cumulative incidence of clinical ketosis at the study dairy farm

The mean monthly cumulative incidence of CK over the four years was 0.53% (40/7511; 95% CI: 0.38, 0.72) and it differed among the four years (Friedman test = 15.11, $p < 0.01$; Fig. 2B and Table 3). The median of the mean

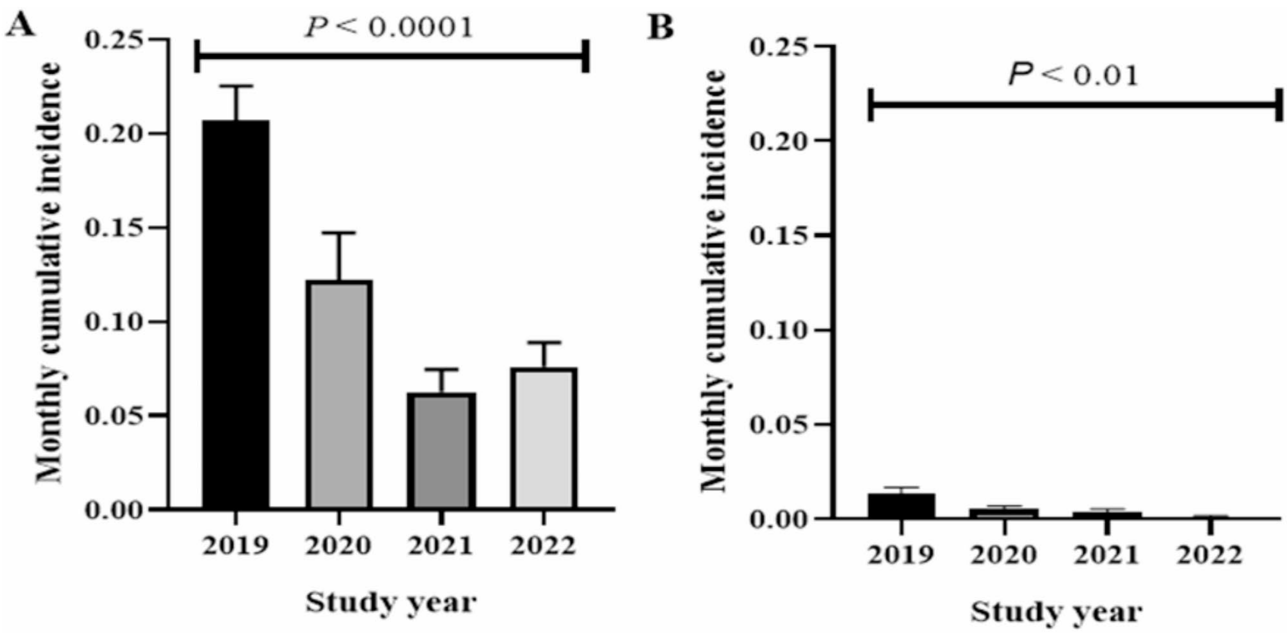

Fig. 2 The Mean monthly cumulative incidences of subclinical and clinical ketosis for four years at the anonymous dairy farm. The monthly cumulative incidences of subclinical ketosis (**panel A**) and clinical ketosis (**panel B**) progressively declined beginning from 2019 to 2022

Table 1 Mean monthly cumulative incidence of subclinical ketosis at the study dairy farm ($N=7511$)

Risk factors	Category	No. of tested cows	No. of positive for SCK	% ± SEM	χ^2	*p* value
Study year ($N=7511$)	2019	1699	352	20.7 ± 0.98	247.029	< 0.0001
	2020	1763	220	12.5 ± 0.79		
	2021	1983	119	6.0 ± 0.53		
	2022	2066	147	7.1 ± 0.57		
Season ($N=7511$)	Summer	1942	193	9.9 ± 0.68	75.578	< 0.0001
	Autumn	2119	189	8.9 ± 0.62		
	Winter	1706	289	16.9 ± 0.91		
	Spring	1744	167	9.6 ± 0.71		
Body score ($N=6377$)	1.0–3.0	1917	219	11.4 ± 0.73	2.306	0.316
	3.1–4.0	3401	433	12.7 ± 0.57		
	4.1–5.0	1059	137	12.9 ± 1.0		
Parity ($N=7511$)	Parity 1	2819	198	7.0 ± 0.48	224.95	< 0.0001
	Parity 2	2238	179	8.0 ± 0.57		
	Parity 3	1134	197	17.4 ± 1.1		
	Parity 4	671	142	21.2 ± 1.6		
	Parity 5	326	68	20.9 ± 2.3		
	Parity 6	182	33	18.1 ± 2.9		
	Parity 7	141	21	14.9 ± 3.0		

monthly cumulative incidence of CK were 0.015 (95% CI: 0.002, 0.023), 0.003 (95% CI: 0.0, 0.01), 0.0(95% CI:0.0, 0.007), and 0.0 (0.0, 0.007) in 2019, 2020, 2021 and 2022, respectively (Table 3). The mean monthly cumulative incidence of CK was significantly associated with the year (Fischer exact test = 31.03; $p < 0.0001$ and parity number (Fischer exact test = 27.87; $p < 0.0001$). However, it was not associated either with season, or body condition.

Discussion

In the present study, the mean monthly cumulative incidences of SCK and CK were estimated in 7511 freshly calved cows in the UAE based on a 4-year retrospective data. Measuring the concentration of BHB in the blood and examination for clinical signs of ketosis were used were used for defining the ketosis status of the study cows. The average monthly cumulative incidence (11.16%) of SCK recorded by this study was comparable to the 11.2% reported in the Netherlands [20] but much

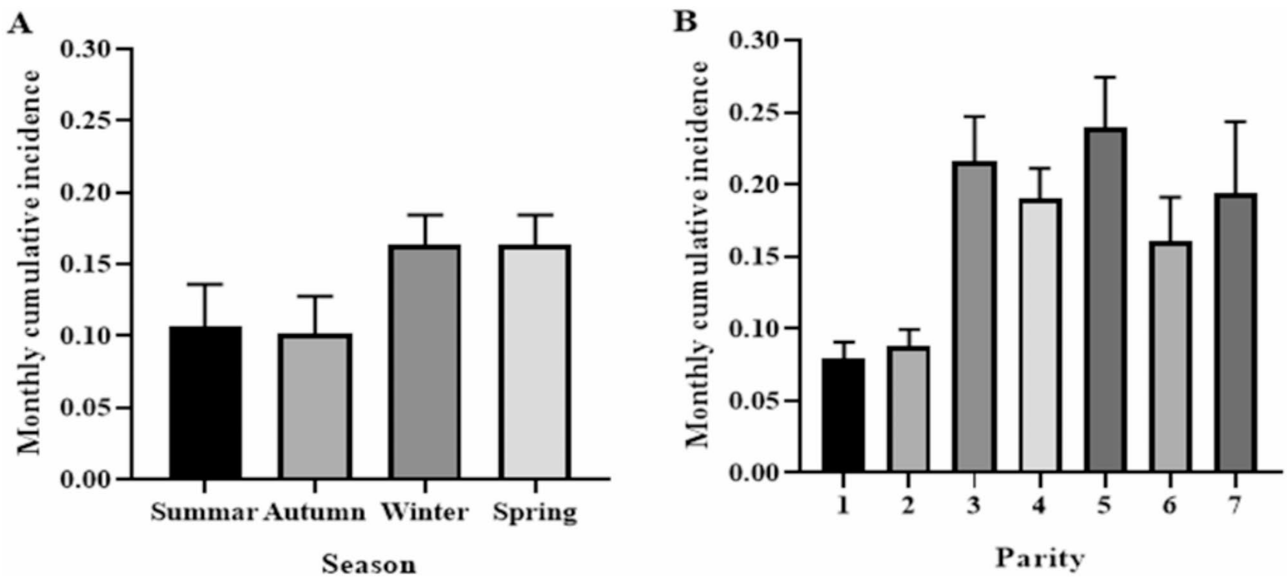

Fig. 3 The Mean monthly cumulative incidence of subclinical ketosis in cows at the different season (**panel A**) and parities (**panel B**). An increasing trend in mean monthly cumulative incidence of SCK was observed as the parity number increased. Relatively high mean monthly cumulative incidence was observed in winter and spring

Table 2 Association of mean monthly cumulative incidence of subclinical ketosis with different risk factors based on univariate and multivariate binary logistic regression analysis

Risk factors	Category	No. of cows Tested	Univariate		Multivariate	
			Crude OR (95% CI)	*P* value	Adjusted OR (95% CI)	*P* value
Study year	2019	1699	4.09 (3.29, 5.20)	< 0.0001	3.75 (3.00, 4.70)	< 0.0001
	2020	1763	2.23 (1.77, 2.82)	< 0.0001	2.10 (1.66, 2.66)	< 0.0001
	2021	1983	1	-	1	-
	2022	2066	1.20 (0.94, 1.54)	0.153	1.33 (1.04, 1.72)	0.026
Season	Summer	1942	1.13 (0.91, 1.39)	0.267	1.12 (0.90, 1.39)	0.309
	Autumn	2119	1	-	1	-
	Winter	1706	2.08 (1.71, 2.53)	< 0.0001	1.90 (1.55, 2.32)	< 0.0001
	Spring	1744	1.08 (0.87, 1.35)	0.483	0.97 (0.77, 1.21)	0.773
Parity	Parity 1	2819	1	-	1	-
	Parity 2	2238	1.15 (0.93, 1.42)	0.190	1.18 (0.95, 1.46)	0.133
	Parity 3	1134	2.78 (2.25, 3.44)	< 0.0001	2.30 (1.86, 2.86)	< 0.0001
	Parity 4	671	3.55 (2.81, 4.49)	< 0.0001	3.19 (2.51, 4.06)	< 0.0001
	Parity 5	326	3.49 (2.57, 4.73)	< 0.0001	3.49 (2.55, 4.77)	< 0.0001
	Parity 6	182	2.93 (1.96, 4.39)	< 0.0001	2.63 (1.74, 3.97)	< 0.0001
	Parity 7	141	2.32 (1.43, 3.77)	0.001	2.36 (1.43, 3.88)	0.001

lower than the 49% reported in France [21]. Two different groups of researchers [22, 23] indicated that most studies on ketosis were mainly from Europe, the Americas, Oceania, and a few Asian countries. Thus, since no study was published on ketosis from the Middle East and east Africa, the result of the present study could not be compared with results reported from the region or nearby countries. Besides, most studies on ketosis were prevalence reports but studies reporting incidence were scarce. It is known that prevalence and incidence are different by their definitions, but they are also directly related as both measure disease quantification. For this reason, our mean monthly cumulative incidence was also compared with prevalence reports for the rough assessment of our results with the results of other studies.

A review published by a group of researchers [7] showed that the average prevalence of SCK in 10 European countries was 21.8% (ranging from 11.2 to 36.6%). Similarly, Brunner et al. [24] reported prevalence values of 17% in South Africa, 28.5% in Asia, 13.3% in Central and South America, and 24.85% in Oceania. In addition, a few studies conducted on the incidence rate of SCK reported incidence rates ranging from 19.7 cases per 100 cows-year [6] to 44.0 cases per 100 cows-year [25]. Thus,

Table 3 The association of the mean monthly cumulative incidence of clinical ketosis with potential risk at the study farm ($N=7511$)

Risk factors	Category	No. of tested cows	No. of positive for CK	% ± SEM	χ^2	*p* value
Study year	2019	1699	23	1.35 ± 0.28	31.03*	< 0.01
	2020	1763	9	0.51 ± 0.17		
	2021	1983	6	0.30 ± 0.12		
	2022	2066	2	0.01 ± 0.07		
Season	Summer	1942	11	0.57 ± 0.17	5.46	0.141
	Autumn	2119	5	0.24 ± 0.11		
	Winter	1706	11	0.64 ± 0.19		
	Spring	1744	13	0.75 ± 0.21		
Body score	1.0–3.0	1917	9	0.47 ± 0.16	1.63	0.443
	3.1–4.0	3401	22	0.65 ± 0.14		
	4.1–5.0	1059	9	0.85 ± 0.28		
Parity	Parity 1	2819	6	0.21 ± 0.09	27.87*	< 0.0001
	Parity 2	2238	6	0.27 ± 0.11		
	Parity 3	1134	11	0.97 ± 0.29		
	Parity 4	671	11	1.64 ± 0.49		
	Parity 5	326	4	1.23 ± 0.61		
	Parity 6	182	1	0.55 ± 0.54		
	Parity 7	141	1	0.71 ± 0.70		

* *Fisher's exact test*

it can roughly be assumed that the results of the burden of ketosis reported by these studies could be higher than the burden ketosis that is recorded by this study.

The average monthly cumulative incidence of CK over the four years was 0.53% and it was similar with those reported earlier by other researchers [26]. Although studies on CK are largely scarce; the few studies conducted reported that the prevalence ranges from 0.0% in Brazil and South Africa to 11.10% in Italy [23]. Furthermore, another study reported an incidence rate of 2.4 cases per 100 cows-year [26], which could be roughly similar to the mean monthly cumulative incidence recorded by this study.

The relatively low average monthly cumulative incidence could partly be due to the management of the study farm and its feeding practices. The farm adopted optimal management and feeding system to its lactating cows. The milking herd was fed on a total mixed ration (TMR) four times daily. TMR is routinely analyzed using near-infrared technology that validates the chemical ingredients of the feed. TMR includes good quality forages, a balance of grains and proteins, vitamins, and minerals. Previous studies also reported a low incidence of ketosis in a farm with good management and feeding system [27].

The association between the average monthly cumulative incidence of either SCK or CK and the different potential risk factors was investigated using binary logistic regression (the likelihood ratio tests). The average monthly cumulative incidences of both SCK and CK decreased beginning from 2019 to 2022, which could be due to a progressive improvement in the management of the study farm including the improvement of feed quality as explained above.

Regarding season, it was observed that the incidence of SCK increased in winter. This could be due to the requirement of additional energy for cows to keep themselves warm during the winter on top of the energy required for milk production and survival. The effect of season on the incidence or prevalence of ketosis was reported by different researchers. According to the review published earlier [22], several authors generally agreed to consider spring as the season with a high incidence or prevalence of ketosis. Other authors reported high prevalence (or incidence) values during the late autumn and winter [27, 28]. Furthermore, other authors reported a high prevalence of ketosis in the summer season [7, 20].

Parity number was associated with the average monthly cumulative incidence of SCK. This observation is in agreement with the reports of several similar studies [27, 29]. For example, in this study, the average monthly cumulative incidence of SCK increased from 7% at parity 1 to 21% at parity 4. Similarly, an increase in cumulative incidence from 8.6% at the first parity to 26.2% at the third or greater parity was reported earlier [29]. The increase in the incidence or prevalence of ketosis with an increase in parity. This could be associated with the concurrent increase in milk production which increases negative energy balance leading to the mobilization of body fat and release of ketone bodies. Contrary to this observation, a study conducted in Jersey breed reported a higher prevalence of ketosis in primiparous cows than in multiparous cows [30].

Regarding body condition, the average monthly cumulative incidence of SCK in cows with thin, moderate, and fat body conditions were 11.4%, 12.7%, and 12.9%, respectively showing low increase with increase in body condition although the increase was not statistically significant. Many studies reported a significantly higher incidence of ketosis in cows with fat and moderate body conditions than in cows with thin body conditions [6, 28, 31, 32]. The higher incidence of ketosis in cows with good body condition could be due to reduction of dry matter intake (DMI) by fat cows during pre-calving which leads to the development of SCK post-calving because of negative energy balance [1]. Such cows therefore mobilize fat reserves excessively leading to ketosis [1]. Furthermore, the higher incidence (or prevalence) of ketosis in fat cows could be associated with a large amount of fat storage in these cows and its mobilization following the occurrence of negative energy balance.

Although ketosis is economically important disease, it was not possible assess its economic loss in the study farm because of failure to collect data. The economic losses due to ketosis have been published in the literature from different countries. Accordingly, both CK and SCK cause direct and indirect economic losses. The direct economic losses are caused by reduced milk production, delay in pregnancy, culling of cows, death of cows, and treatment and replacement costs of ketosis while the indirect economic losses are instigated through disposing cows to other diseases including mastitis, metritis, displaced abomasum, retained placenta, lameness, endometritis and other infectious diseases [33–36]. Raboisson et al. [35], estimated economic loss of SCK at €257 per case while Gohary et al. [36] estimated the economic loss of SCK at $203 per case. Additionally, Mostert et al. [33] reported economic loss of €130 per case per year due to SCK in Dutch dairy farms. Furthermore, Steeneveld et al. [34] reported an economic loss of €150 per lactating cow.

Limitations of the study

The study was conducted on a single farm which could limit the external validity of the result of the study. On the other hand, the total number of lactating cows included in the study was 7511 and the data extraction was done for four years, which could show the strength of the study. Furthermore, the setup and feeding system of dairy farms in the UAE are similar and the majority of the farms raise the Holstein Friesian breed, use zero grazing-based intensive farming, use water spray-based cooling system, and depend on imported feed.

Conclusion

The mean monthly cumulative incidence of CK was low while that of SCK was moderate at the study farm. Therefore, control and preventive measures of ketosis are recommended to reduce the incidence of SCK at the study farm.

Abbreviations

BHB	β-hydroxybutyrate
CK	Clinical ketosis
DIM	Day in milk
DMI	Dry matter intake
IQR	Interquartile range
NIR	Near-infra-red
SCK	Subclinical ketosis
TMR	Total mixed ration
UAE	United Arab Emirates

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12917-025-04726-8.

Supplementary Material 1

Acknowledgements

The authors are grateful to the administration of the study farm for allowing access to dairy records for data extraction.

Author contributions

GA contributed in conceptualizing and leading the study, supporting the data analysis, and drafting and editing of the manuscript. BB contributed in the data analysis, interpretation, and edition of the manuscript. SSA, MA, MAO and GK contributed in data collection. AZ, AA, and TM contributed in data entry and edition. KM, MSA, YME, and MEH contributed in editing the manuscript. BAD contributed in reviewing and discussing the economic loss aspect of the study. IH, TS and MT contributed in the interpretationof the results and edition of the manuscript. All authors contributed to the article and approved the submitted version.

Funding

This study was funded by the United Arab Emirates University through its SURE PLUS Program. The reference number of the grant was G00003868. The principal author and some of the co-authors are employees of the United Arab Emirates University which funded the study.

Data availability

The data used for this study have been submitted with the manuscript in Excel file as a supplementary file.

Declarations

Ethics approval and consent to participate

Ethical approval was not required for the animal study since retrospective data which were collected as part of the routine dairy farm activities were used. Approval was obtained from the management of the Farm to use the data of the Farm for this study. All methods were performed in accordance with the relevant guidelines and regulations.

Consent for publication

Verbal consent for publication has been obtained from the farm manager during data extraction.

Competing interests

The authors declare no competing interests.

Received: 29 May 2023 / Accepted: 31 March 2025
Published online: 28 April 2025

References

1. Herdt TH. Ruminant adaptation to negative energy balance: influences on the etiology of ketosis and fatty liver. Vet Clin North Am Food Anim Pract. 2000;16:215–30.
2. Lisuzzo A, Laghi L, Faillace V, Zhu C, Contiero B, Morgante M, et al. Differences in the serum metabolome profile of dairy cows according to the BHB concentration revealed by proton nuclear magnetic resonance spectroscopy (1H-NMR). Sci Rep. 2022;12:2525.
3. Fiore E, Lisuzzo A, Laghi L, Harvatine KJ, Mazzotta E, Alterisio MC, et al. Serum metabolomics assessment of etiological processes predisposing ketosis in water Buffalo during early lactation. J Dairy Sci. 2023;106:3465–76.
4. Oetzel GR. Monitoring and testing dairy herds for metabolic disease. Vet Clin North Am Food Anim Pract. 2004;20:651–74.
5. Duffield TF, Lissemore KD, McBride BW, Leslie KE. Impact of hyperketonemia in early lactation dairy cows on health and production. J Dairy Sci. 2009;92:571–80.
6. McArt JAA, Nydam DV, Oetzel GR, Overton TR, Ospina PA. Elevated non-esterified fatty acids and β-hydroxybutyrate and their association with transition dairy cow performance. Vet J. 2013;198:560–70.
7. Suthar VS, Canelas-Raposo J, Deniz A, Heuwieser W. Prevalence of subclinical ketosis and relationships with postpartum diseases in European dairy cows. J Dairy Sci. 2013;96:2925–38.
8. Walsh S, Buckley F, Berry DP, Rath M, Pierce K, Byrne N, et al. Effects of breed, feeding system, and parity on udder health and milking characteristics. J Dairy Sci. 2007;90:5767–79.
9. Roberts T, Chapinal N, LeBlanc SJ, Kelton DF, Dubuc J, Duffield TF. Metabolic parameters in transition cows as indicators for early-lactation culling risk. J Dairy Sci. 2012;95:3057–63.
10. Chapinal N, Carson ME, LeBlanc SJ, Leslie KE, Godden S, Capel M, et al. The association of serum metabolites in the transition period with milk production and early-lactation reproductive performance. J Dairy Sci. 2012;95:1301–9.
11. Hoeben D, Burvenich C, Massart-Leën A-M, Lenjou M, Nijs G, Van Bockstaele D, et al. In vitro effect of ketone bodies, glucocorticosteroids and bovine pregnancy-associated glycoprotein on cultures of bone marrow progenitor cells of cows and calves. Vet Immunol Immunolpathol. 1999;68:229–40.
12. Suriyasathaporn W, Daemen AJ, Noordhuizen-Stassen EN, Dieleman SJ, Nielen M, Schukken YH. Beta-hydroxybutyrate levels in peripheral blood and ketone bodies supplemented in culture media affect the in vitro chemotaxis of bovine leukocytes. Vet Immunol Immunopathol. 1999;68:177–86.
13. Global Food Security Index. Global Food Security Index (GFSI). Global Food Security Index (GFSI). 2023. https://impact.economist.com/sustainability/project/food-security-index. Accessed 28 May 2023.
14. TDRA. National Food Security Strategy 2051.Telecommunication and Digital Government Regulatory Authority. TDRA. Commitbiz. 2023. https://tdra.gov.ae/. Accessed 13 Jun 2024.
15. van Dijk Z, Upward trend for UAE dairy products Dairy Global. (2021). Available online at: https://www.dairyglobal.net. Dairy Global. 2021. Accessed 13 Jun 2024.
16. DairyComp 305. DairyComp 305. Slashdot. 2024. https://slashdot.org/software/p/DairyComp-305/. Accessed 13 Jun 2024.
17. Michael Thrusfield RC. Veterinary Epidemiology, 4th Edition| Wiley. Wiley.com. 2018.Accessed 28 May 2023.
18. Iwersen M, Falkenberg U, Voigtsberger R, Forderung D, Heuwieser W. Evaluation of an electronic Cowside test to detect subclinical ketosis in dairy cows. J Dairy Sci. 2009;92:2618–24.
19. Pineda A, Cardoso FC. Technical note: validation of a handheld meter for measuring β-hydroxybutyrate concentrations in plasma and serum from dairy cows. J Dairy Sci. 2015;98:8818–24.
20. van der Drift SGA, Jorritsma R, Schonewille JT, Knijn HM, Stegeman JA. Routine detection of hyperketonemia in dairy cows using fourier transform infrared spectroscopy analysis of β-hydroxybutyrate and acetone in milk in combination with test-day information. J Dairy Sci. 2012;95:4886–98.
21. Berge AC, Vertenten G. A field study to determine the prevalence, dairy herd management systems, and fresh cow clinical conditions associated with ketosis in Western European dairy herds. J Dairy Sci. 2014;97:2145–54.
22. Benedet A, Manuelian CL, Zidi A, Penasa M, De Marchi M. Invited review: β-hydroxybutyrate concentration in blood and milk and its associations with cow performance. Animal. 2019;13:1676–89.
23. Lei MAC, Simões J. Invited review: ketosis diagnosis and monitoring in High-Producing dairy cows. Dairy. 2021;2:303–25.
24. Brunner N, Groeger S, Canelas Raposo J, Bruckmaier RM, Gross JJ. Prevalence of subclinical ketosis and production diseases in dairy cows in central and South America, Africa, Asia, Australia, new Zealand, and Eastern Europe1. Transl Anim Sci. 2019;3:84–92.
25. Kaufman EI, Asselstine VH, LeBlanc SJ, Duffield TF, DeVries TJ. Association of rumination time and health status with milk yield and composition in early-lactation dairy cows. J Dairy Sci. 2018;101:462–71.
26. Weigel Ka, Pralle RS, Adams H, Cho K, Do C, White H. m. Prediction of whole-genome risk for selection and management of hyperketonemia in Holstein dairy cattle. (GJABG)2017;134:275–85.
27. Santschi DE, Lacroix R, Durocher J, Duplessis M, Moore RK, Lefebvre DM. Prevalence of elevated milk β-hydroxybutyrate concentrations in Holstein cows measured by Fourier-transform infrared analysis in dairy herd improvement milk samples and association with milk yield and components. J Dairy Sci. 2016;99:9263–70.
28. Vanholder T, Papen J, Bemers R, Vertenten G, Berge ACB. Risk factors for subclinical and clinical ketosis and association with production parameters in dairy cows in the Netherlands. J Dairy Sci. 2015;98:880–8.
29. Rathbun FM, Pralle RS, Bertics SJ, Armentano LE, Cho K, Do C, et al. Relationships between body condition score change, prior mid-lactation phenotypic residual feed intake, and hyperketonemia onset in transition dairy cows. J Dairy Sci. 2017;100:3685–96.
30. Chandler TL, Pralle RS, Dórea JRR, Poock SE, Oetzel GR, Fourdraine RH, et al. Predicting hyperketonemia by logistic and linear regression using test-day milk and performance variables in early-lactation Holstein and Jersey cows. J Dairy Sci. 2018;101:2476–91.
31. Duffield TF, Sandals D, Leslie KE, Lissemore K, McBride BW, Lumsden JH, et al. Efficacy of Monensin for the prevention of subclinical ketosis in lactating dairy cows. J Dairy Sci. 1998;81:2866–73.
32. Gillund P, Reksen O, Gröhn YT, Karlberg K. Body condition related to ketosis and reproductive performance in Norwegian dairy cows. J Dairy Sci. 2001;84:1390–6.
33. Mostert PF, Bokkers EaM, van Middelaar CE, Hogeveen H, de Boer IJM. Estimating the economic impact of subclinical ketosis in dairy cattle using a dynamic stochastic simulation model. Animal. 2018;12:145–54.
34. Steeneveld W, Amuta P, Van Soest FJS, Jorritsma R, Hogeveen H. Estimating the combined costs of clinical and subclinical ketosis in dairy cows. PLoS ONE. 2020;15:e0230448.
35. Raboisson D, Mounié M, Khenifar E, Maigné E. The economic impact of subclinical ketosis at the farm level: tackling the challenge of over-estimation due to multiple interactions. Prev Vet Med. 2015;122:417–25.
36. Gohary K, Overton M, von Massow M, LeBlanc S, Lissemore K, Duffield T. The cost of a case of subclinical ketosis in Canadian dairy herds. (The CVJ). 2016;57:728–32.

Publisher's note