Blood Gas and Acid-Base Values in the Coccygeal Artery of Holstein-Friesian Cows

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ABSTRACT. The pH, P_{CO_2} , P_{O_2} , HCO_3^- , and CO_2 content were determined in the blood of the coccygeal artery in 108 Holstein-Friesian cows. The mean values obtained at 39°C and 37°C (in parentheses) were: pH 7.464 (7.494), P_{CO_2} 39.1 (35.9) mmHg, P_{O_2} 107.2 (93.0) mmHg, HCO_3^- 27.4 (26.8) mEq/L and CO_2 content 28.4 (27.9) mEq/L. Between blood samples from the coccygeal artery and those from the jugular vein of 35 of the total cows collected simultaneously, a correlation was observed in the pH, HCO_3^- and CO_2 content, but no correlation was found in the P_{CO_2} and P_{O_2} values. The correlation between the blood pH and the rumen fluid pH was not significant in 22 of the total cows examined.

Recently, accurate and simple methods have become available for determination of the pH value and gas concentrations in the blood by an automatic analyzer. They are important for diagnosis and treatment of the diseased cattle showing disturbances in the acid-base balance.

Blood sampling from the tail is a widely-used technique in cattle. This technique is not so difficult, and it is easier to take the arterial blood from the tail than from any other site [5]. However, little information on the normal values of the pH and gases of the coccygeal arterial blood is available for the healthy cows [1].

The purpose of this report is to give the normal values of the pH and gases in the arterial blood of healthy Holstein-Friesian cows. In addition, the values obtained with the blood from the coccygeal artery were compared with those from the jugular vein, and the blood pH and the rumen fluid pH were compared each other.

MATERIALS AND METHODS

Experimental Animals: A total of 108 Holstein-Friesian cows were used in the present study. They were clinically healthy and maintained on six farms in Iwate prefecture, Japan.

Collection of Blood Samples: Blood samples were collected anaerobically from the coccygeal artery and the jugular vein of each cow into a syringe containing heparinate. Arterial samples were collected by a modification of Ghoshal and Getty's tail bleeding technique [5]. In this technique the tail was pulled upward and an 18-gauge arterial needle attached to a 10-ml syringe was inserted into the coccygeal artery at a level of the 3rd or 4th coccygeal vertebra.

Analytical Methods: The blood pH, P_{CO_2} , P_{O_2} , HCO_3^- and CO_2 content were determined with an IL-513 digital pH blood gas analyzer (Instrumentation Laboratories, Lexington, MA, U.S.A.) with a blood gas control solution (showing pH 7.36-7.46, P_{CO_2} of 45-50 mmHg and P_{O_2} of 97-107 mmHg) as an external standard. The water bath surrounding the electrodes was kept at 37°C. The values of pH, P_{CO_2} , P_{O_2} , HCO_3^- and CO_2 content obtained at 37°C were corrected to those at body temperature (39°C): $pH_{at\ 39^\circ C} = pH_{at\ 37^\circ C} - 0.0147 (39 - 37)$; $\log P_{CO_2\ at\ 39^\circ C} = 0.019(39 - 37)$; $\log P_{O_2\ at\ 39^\circ C} = 0.031(39 - 37)$; $HCO_3^- = 2.41 \times 10^{-8} \times P_{CO_2} \times 10^{pH}$; and $CO_2\ content = HCO_3^- + 0.0306 P_{CO_2} (10)$. The

rumen fluid was collected 2-4 hr after feeding through a gastric catheter (KT type, Fujihira Co. Ltd., Tokyo). Its pH was determined with a pH meter (Horiba Co. Ltd., Tokyo).

Table 1. Gases and acid-base status of coccygeal arterial blood for healthy Holstein-Friesian cows

		n=108
Item		Mean $\pm$ S.D.
Age (years)		4.7 $\pm$ 2.2
Body temp. ($^{\circ}$ C)		38.7 $\pm$ 0.2
pH	37 $^{\circ}$ C	7.494 $\pm$ 0.029
	39 $^{\circ}$ C	7.465 $\pm$ 0.029
PCO ₂ (mmHg)	37 $^{\circ}$ C	35.9 $\pm$ 3.6
	39 $^{\circ}$ C	39.1 $\pm$ 3.9
PO ₂ (mmHg)	37 $^{\circ}$ C	93.0 $\pm$ 6.5
	39 $^{\circ}$ C	107.2 $\pm$ 7.4
HCO ₃ ⁻ (mEq/L)	37 $^{\circ}$ C	26.8 $\pm$ 2.1
	39 $^{\circ}$ C	27.4 $\pm$ 2.1
CO ₂ ct. (mEq/L)	37 $^{\circ}$ C	27.9 $\pm$ 2.1
	39 $^{\circ}$ C	28.4 $\pm$ 2.2

RESULTS

The mean values and standard deviations for the pH and gases of the coccygeal arterial blood obtained from the 108 Holstein-Friesian cows are given in Table 1. The mean values at 39 $^{\circ}$ C were as follows: pH 7.465, PCO₂ 39.1 mmHg, PO₂ 107.2 mmHg, HCO₃⁻ 27.4 mEq/L and CO₂ content 28.4 mEq/L of blood. Arterial (coccygeal) and venous (jugular) blood samples were collected simultaneously from 35 of the total cows to be determined for pH and gases (Table 2). There was high correlation ($P < 0.001$) in the HCO₃⁻ and CO₂ content between the arterial and the venous blood. There was also a correlation significant at the 0.05 level in the pH value between them. The PCO₂ or PO₂ value exhibited no correlation between them.

The blood gas and acid-base status in relation to the age of adult cows are shown in Table 3. There were no statistically

Table 2. The correlation of gases and acid-base status between coccygeal arterial and jugular venous blood from 35 healthy cows

Blood	pH	PCO ₂ (mmHg)	PO ₂ (mmHg)	HCO ₃ ⁻ (mEq/L)	CO ₂ ct. (mEq/L)
Coccygeal Artery	7.472 $\pm$ 0.031	41.0 $\pm$ 3.1	108.1 $\pm$ 6.2	29.4 $\pm$ 2.7	30.6 $\pm$ 2.0
Jugular Vein	7.400 $\pm$ 0.038	51.9 $\pm$ 6.5	33.3 $\pm$ 3.5	31.4 $\pm$ 2.8	32.9 $\pm$ 2.9
Correlation coefficient	0.41	0.26	0.09	0.68	0.76
Significance	$P < 0.05$	—	—	$P < 0.001$	$P < 0.001$

Sample values are shown at 39 $^{\circ}$ C body temperature.

Table 3. Blood gas and acid-base status of coccygeal arterial blood in relation to ages of cows

Age	Number	pH	PCO ₂ (mmHg)	PO ₂ (mmHg)	HCO ₃ ⁻ (mEq/L)	CO ₂ ct. (mEq/L)
2-3	37	7.458 $\pm$ 0.027	38.8 $\pm$ 3.1	107.5 $\pm$ 4.7	26.8 $\pm$ 1.3	27.9 $\pm$ 1.4
4-5	24	7.463 $\pm$ 0.029	39.0 $\pm$ 4.5	107.5 $\pm$ 6.4	27.2 $\pm$ 2.4	28.3 $\pm$ 2.4
6	29	7.466 $\pm$ 0.027	37.5 $\pm$ 4.3	107.7 $\pm$ 7.7	26.4 $\pm$ 2.2	27.5 $\pm$ 2.2
		—	—	—	—	—
Significance		—	—	—	—	—
		—	—	—	—	—

Sample values are shown at 39 $^{\circ}$ C body temperature.

significant differences at the 0.05 level among the three age groups (2–3, 4–5, of more than 6 years). Furthermore, a total of 22 cows were examined for the correlation between the blood pH and rumen fluid pH values. There was no significant correlation ($r=0.222$) between them.

DISCUSSION

Because of the difficulty in taking arterial blood samples from human beings and animals, venous blood is sometimes used in the clinical practice for determination of acid-base status and blood gas contents. The venous value, however, is not an accurate indicator of actual blood gas or acid-base status [4, 9]. In cattle, blood sampling from the coccygeal artery is simple [5]. There is little information, however, on the normal values of the blood gas and acid-base status of the coccygeal artery of healthy cows [1]. Arterial blood values for gas and acid-base status in healthy calves have been reported by many investigators [2, 8, 11], but only one report is available for these values in healthy adult cattle [3]. The values obtained by Fisher et al. [3] at 39°C are as follows: pH 7.47, P_{CO_2} 36.8 mmHg, and P_{O_2} 103.0 mmHg for the brachial artery and pH 7.43, P_{CO_2} 38.2 mmHg, and P_{O_2} 93.0 mmHg for the auricular artery. The pH value (7.465) of the coccygeal arterial blood estimated by the authors at 39°C is very close to that determined by Fisher et al. [3], but the P_{CO_2} value (39.1 mmHg) obtained by us is a little larger than that reported by them. The difference have been due to different feeding and management of animals. The P_{O_2} value (107.2 mmHg) of the coccygeal arterial blood obtained by us is very close to that of the blood of the brachial artery, and a little higher than that of the blood of the auricular artery. The difference may

be explained by the fact that these arteries supply blood to relatively small areas apart from the heart [3], or that the temperatures of these arterial areas are different from each other.

The most accurate blood pH will be obtained if the electrode is maintained at or near the body temperature [2]. The temperature of the water jacket, however, is commonly maintained at 37°C. The results obtained at this temperature are regarded as standard values in human beings. In the present experiment, the jacket was kept at 37°C, and all the results obtained were converted to those at 39°C [2]. Donawick and Baue [2] suggested that such an experiment like this might be only sensible approach to the determination of standard values in animals.

Rodkey et al. [9] suggested that the pH or gas status in the venous blood might not accurately reflect the blood gas or acid-base status of animals. A correlation was demonstrated between arterial and venous blood in pH, P_{CO_2} , P_{O_2} , HCO_3^- , and CO_2 content values in 34 healthy cows. In the present study, a significant correlation was observed between arterial and venous blood in pH, HCO_3^- , and CO_2 content values, but not in the blood P_{CO_2} or P_{O_2} value. This indicates that P_{CO_2} and P_{O_2} values in the vein are greatly different from those in the artery, from which the blood was drawn [9]. Therefore, the blood gas status in the venous blood does not represent that in the arterial blood.

Moore et al. [6] reported that the venous blood pH was higher in dams than in their calves. No data are available, however, on the blood gas or acid-base value in adult cows of different ages. In the present experiment, blood gas and acid-base values in adult cattle were not different among ages groups.

It is known that in rumen acidosis, the blood pH as well as the rumen fluid pH falls markedly [7]. In the present experiment, there was no correlation in pH between the arterial blood and rumen fluid. This is probably because the rumen fluid may possess a buffer action in healthy normal cattle.

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要 約

乳牛の尾動脈血における血液ガス・酸塩基平衡の標準値について：内藤善久・村上大蔵（岩手大学農学部家畜内科学教室）——牛における血液ガス・酸塩基平衡の異常を的確に診断，治療するための基礎資料を得ることを目的として，健康牛 108 頭の尾動脈血における標準値を求め，以下の成績をえた。

- 1) 108 頭のホルスタイン種乳牛の尾動脈血の 39°C における平均値・標準偏差は，pH: 7.465 ± 0.029 , P_{CO_2} : 39.1 ± 3.9 mmHg, P_{O_2} : 107.2 ± 7.4 mmHg, HCO_3^- : 27.4 ± 2.1 mEq/L および CO_2 含量: 28.4 ± 2.2 mEq/L であった。
- 2) 尾動脈血の HCO_3^- 濃度， CO_2 含量および pH 値と，頸静脈血のそれらの値との間には有意の正相関を認めたが， P_{CO_2} 値および P_{O_2} 値には相関を認めなかった。
- 3) 成牛血液 pH については年齢の違いによる有意差を認めなかった。
- 4) 尾動脈血 pH と第一胃汁 pH との間には有意の相関は認められなかった。