Effects of Feed and Water Intakes on Whole Blood Viscosity and Plasma Osmolality in Broiler Chickens

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Two experiments were carried out to determine the effect of feed and water intakes on whole blood viscosity in broiler chickens. In experiment 1, three feeding levels (25, 50 and 75 g/bird) were provided to three groups of birds at 08.00 h, respectively. After feeding, each bird was allowed to drink 100 ml water at 09.00 h. In experiment 2, two levels of water (50 and 150 ml/bird) were given to two group birds, after 50 g/bird feed was taken, at 09.00 h. WBV and plasma osmolality (PO) increased with the increase of feed intake, and decreased with time after feeding. However, in 25 g feed intake birds, PO increased with time after feeding. Plasma protein concentration (PPC) was ($P < 0.05$) higher at 50 and 75 g than at 25 g feeding level. No significant differences were found in haematocrit (HCT) and plasma viscosity (PV) between feeding levels. There was no significant difference in PPC, HCT or PV between the two drinking levels. PO had a significantly ($P < 0.05$) lower value at 150 ml compared to at 50 ml at 09.30 h, although no significant difference was found in WBV. Moreover, WBV and PO tended to decrease with time at 50 ml, while to increase at 150 ml. As described above, WBV and PO increased with the increase of feed intake, but their changes with time after feeding were related to a water/feed ratio.

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Key words : blood viscosity, broiler chicken, feed intake, plasma osmolality, water intake

Introduction

It is well known that heat-exposure induces an increase in water intake and a reduction in feed intake in broiler chickens. It has been noticed that whole blood viscosity (WBV) and haematocrit (HCT) decreased significantly when broilers were exposed to high temperature (ZHOU *et al.*, 1997). Such decrease is likely to be related to the reduction in feed intake and the increase in water intake. HOCKING *et al.* (1994) reported that WBV and plasma viscosity (PV) were significantly lower in chronically restricted-fed broiler breeders than in *ad libitum*-fed birds. ZHOU *et al.* (1998a) found that WBV and HCT, compared to *ad libitum*-fed broilers, were markedly lower in the birds deprived of feed and water for 15 h, and tended to be higher after deprivation of feed and water for 21 h.

Under the conditions of feeding and drinking *ad libitum*, red blood cells, HCT, plasma protein concentration (PPC) of broiler decreased during high ambient temper-

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ature (DEATON *et al.*, 1969 ; KUBENA *et al.*, 1972 ; DONKOH, 1989 ; YAHAV *et al.*, 1997 ; ZHOU *et al.*, 1997, 1998 a). However, many reports indicated that water withdrawal induced an increase in HCT and PPC, even though the animals were kept under thermoneutral environment. In broilers reared under standard conditions, there was no change in HCT within 6 h after feed and water withdrawal, but an increase after feed and water withdrawal exceeded 6 h (SCOTT *et al.*, 1983). KOIKE *et al.* (1983) reported that HCT was significantly higher in chickens deprived of water for 24 h or more, than in control group birds. A significant reduction, with the increase in feed restriction period, was observed in red and white blood cells and thrombocyte numbers together with significant increase in mean cell haemoglobin and mean cell volume in the broiler chickens, in which early feed restriction (14 g/d/bird) was carried out for 6, 10 or 14 days from 6-d-old (MAXWELL *et al.*, 1991).

As described above, feed and water restrictions influence haematology. However, how the extent of feed or water intake influences haematology and blood rheology has not been studied sufficiently. This study, therefore, was designed to determine the effects of feed and water intakes on WBV, HCT, PV, PPC and plasma osmolality (PO) of broiler chickens under thermoneutral environment in order to explain whether the decrease in WBV due to heat exposure (ZHOU *et al.*, 1997) could be related to feed and water intakes.

Materials and Methods

Commercial male broiler chickens (Chunky) were used in this study. After 40-d-old, the birds were kept in individual cages (25×45×38 cm) at an ambient temperature of $20.0 \pm 1.0^{\circ}\text{C}$ and a relative humidity of 60–70%, and provided twice with a commercial grower ration (ME 13.2 MJ/kg, CP 180 g/kg ; New Power, Nichiwa Sangyo Co. Ltd., Japan) at 08.00 and 16.00 h each day. They were trained and allowed to take feed as much as possible within 1 h from 08.00 and 16.00 h, respectively, before experiment. Water of 200 ml was supplied to each bird from 09.00 h each day. The lighting pattern was 14 L : 10 D.

Experiment 1

This experiment was conducted to determine the effect of feed intake. Twenty-four birds were divided into 3 groups (8 birds/group) at random. Each group of birds were provided with 25, 50 or 75 g of feed for each bird at 08.00 h at 51-d-old (body weight : 3.10 ± 0.11 kg), respectively. After the feed was taken, each bird was allowed to drink 100 ml water by a vinyl tube (id 1.5 mm, od 3 mm), which was inserted into crop from mouth, at 09.00 h.

Experiment 2

This experiment was conducted to determine the effect of water intake. Each bird was provided with 50 g of feed at 08.00 h at 51-d-old (body weight : 3.05 ± 0.15 kg). Sixteen birds were divided into 2 groups (8 birds/group) at random. One group birds, after feed was taken, was allowed to drink 50 ml/bird water at 09.00 h as Experiment 1,

while the other group birds 150 ml/bird.

Blood sampling and the measurements of blood parameters

Approximately 1.5 ml of blood was collected using a syringe containing a drop of heparin solution (1000 IU heparin/ml, Novo Heparin, Marion Mereru Dau Co., Ltd, Osaka, Japan) from a wing vein of each bird at 09.30, 12.30 and 15.30 h, respectively. The blood was used for the measurement of WBV. WBV was measured using a Cannon-Manning Semimicroviscometer (150, Kusano Scientific Instrument MFG Co., Ltd, Tokyo, Japan) as described by ZHOU *et al.* (1997). Plasma was obtained by centrifuging for 15 min at 3,500 rpm after the measurement of WBV, then used for the measurement of viscosity and protein concentration. PV was measured by the same technique as WBV. PPC was measured using a clinical protein meter (T2-Se, Atago Co., Ltd, Tokyo, Japan). PO was determined using a semi-micro osmometer (Knauer, KG Dr. Herbert Knauer & Co. GmbH, Berlin, Germany) as described by ZHOU *et al.* (1998). HCT was determined using microhematocrit capillary tubes (Terumo VC-H 075 H, Terumo Co., Ltd, Tokyo, Japan) by centrifuging for 5 min at 12,000 rpm.

Statistical analyses

A two-way analysis of variance was used to determine the significance with feed intake or water intake and blood sampling time. Tukey's multiple comparison test (ISHIMURA, 1992) was used to test the significance between means.

Results

Experiment 1

Changes in HCT, WBV, PV, PPC and PO with feed intake are shown in Table 1. WBV increased with the increase of feed intake and was significantly ($P < 0.05$) higher at 75 g than at 50 and 25 g feeding level at any sampling time. In addition, WBV decreased with time after feeding at 50 and 75 g feeding levels. HCT tended to reduce with time, but no marked differences were found between feeding levels. There was no difference in PV between feeding levels or between sampling time points. At 09.30 h, PPC was significantly ($P < 0.05$) higher at 75 and 50 g than at 25 g feed intake. PO increased with the increase of feed intake, and decreased with time after feeding, while increased with time at 25 g.

Experiment 2

Table 2 shows changes in HCT, WBV, PV, PPC and PO with water intake. No marked difference was found in HCT, PV or PPC between the levels of water intake. WBV was similar between 50 and 150 ml water intake at 09.30 h, while significantly ($P < 0.05$) higher at 150 ml than at 50 ml drinking level at 12.30 and 15.30 h. Moreover, WBV decreased with time after drinking at 50 ml water intake, while tended to increase at 150 ml. PO was significantly ($P < 0.05$) higher at 50 ml than at 150 ml at 09.30 h, and decreased with time after drinking at 50 ml, while tended to increase at 150 ml.

Table 1. Changes in haematocrit, whole blood viscosity, plasma viscosity, plasma protein concentration and plasma osmolality of broilers with feed intake

	Feed intake (g)		
	25	50	75
Haematocrit (%)			
9 : 30	27.7±0.7	28.3±0.8	28.5±0.9
12 : 30	27.8±0.6	27.1±0.8	27.5±1.1
15 : 30	27.4±0.5	26.2±0.8	27.3±1.1
Whole blood viscosity (cp)			
9 : 30	2.258±0.083 ^A	2.423±0.080 ^{Ab}	2.582±0.126 ^B
12 : 30	2.329±0.057 ^A	2.399±0.070 ^{Ab}	2.493±0.153 ^B
15 : 30	2.331±0.065 ^A	2.202±0.077 ^{Aa}	2.414±0.129 ^B
Plasma viscosity (cp)			
9 : 30	0.977±0.013	1.001±0.014	0.998±0.008
12 : 30	0.986±0.011	0.977±0.010	0.991±0.011
15 : 30	0.985±0.015	0.977±0.013	0.977±0.015
Plasma protein concentration (g/100 ml)			
9 : 30	2.9±0.1 ^A	3.2±0.1 ^{Bb}	3.2±0.1 ^{Bb}
12 : 30	2.9±0.1	3.0±0.1 ^a	3.0±0.1 ^a
15 : 30	2.9±0.2	2.9±0.1 ^a	2.9±0.1 ^a
Plasma osmolality (mOsm/kg H ₂ O)			
9 : 30	292.3±1.9 ^{Aa}	307.0±2.5 ^{Bc}	313.7±2.2 ^{Cb}
12 : 30	293.3±2.5 ^{Aab}	297.7±3.1 ^{Bb}	304.1±2.8 ^{Ca}
15 : 30	296.4±2.1 ^{Ab}	291.1±2.0 ^{Ba}	305.6±4.7 ^{Ca}

Mean±SE (n=8).

Each bird was forced to drink water 100 ml after eating ceased at 09.00 h.

^{A,B,C} : Significant differences between different superscripts within the same row (P<0.05).

^{a,b,c} : Significant differences for each variable between different superscripts within the same column (P<0.05).

Discussion

The fact that long-term feed restriction induced a reduction in WBV (HOCKING *et al.*, 1994) was also observed in short-term fed-restricted birds in this study. WBV increased significantly with the increase of feed intake. However, no marked differences were found in HCT and PV, which are closely related to WBV (CHIEN, 1982 ; STURKIE and GRIMINGER, 1986 ; SMITH and KAMPINE, 1990 ; MAEDA, 1996), between feeding levels. This may be caused by a larger number of smaller erythrocytes in circulation or a larger number of component parts in plasma in the birds fed a larger amount of feed. HOCKING *et al.* (1994) reported that red blood cells and plasma triglyceride tended to be higher in *ad libitum*-fed fat line birds than in restricted birds. PO, which reflects solute concentration in plasma, increased with the increase of feed intake in this study. The increase in PO probably induces a water shift from blood cells to plasma, resulting in a smaller cell size. In addition, there was no marked difference in PV, even though

Table 2. Changes in haematocrit, whole blood viscosity, plasma viscosity, plasma protein concentration and plasma osmolality of broilers with water intake

	Water intake (ml)	
	50	150
Haematocrit (%)		
9 : 30	27.0±0.7	28.4±0.6
12 : 30	26.4±0.7	27.4±0.5
15 : 30	26.4±0.7	27.1±0.7
Whole blood viscosity (cp)		
9 : 30	2.372±0.062	2.367±0.044
12 : 30	2.320±0.095 ^A	2.473±0.076 ^B
15 : 30	2.239±0.060 ^A	2.438±0.060 ^B
Plasma viscosity (cp)		
9 : 30	1.010±0.012	0.995±0.018
12 : 30	1.013±0.032	0.993±0.022
15 : 30	1.000±0.005	1.002±0.026
Plasma protein concentration (g/100 ml)		
9 : 30	3.3±0.1	3.3±0.2
12 : 30	3.1±0.1	3.2±0.2
15 : 30	3.1±0.1	3.3±0.2
Plasma osmolality (mOsm/kg H ₂ O)		
9 : 30	300.4±2.1 ^{Bb}	291.3±2.8 ^{Aa}
12 : 30	295.0±1.6 ^a	298.6±3.4 ^b
15 : 30	291.9±2.9 ^a	298.0±4.4 ^b

Mean±SE (n=8).

Feed intake was 50 g/bird from 8 : 00 to 9 : 00.

^{A,B} : Significant differences between different superscripts within the same row (P<0.05).

^{a,b} : Significant differences for each variable between different superscripts within the same column (P<0.05).

PPC, related to PV (ZHOU *et al.*, 1998 a), was significantly higher at 50, 75 g feeding levels than at 25 g at 09.30 h (Table 1). This may indicate that PV is not susceptible to the change in PPC as observed in a previous study (ZHOU *et al.*, 1998 b).

WBV and HCT tended to decrease with time after feeding, irrespective of feed intake. This phenomenon may be caused by the following reasons. Firstly, this may be due to a diurnal variation in haematology. ZHOU *et al.* (1998 a) observed that WBV, HCT and red blood cells were lowest at 15.00 h in the birds being able to access to feed and water *ad libitum*. Secondly, the higher PO may induce that some water enters into blood vessels from interstitial space and alimentary tract, resulting in hemodilution. PPC and PO decreased with time at 75 and 50 g feeding levels may reflect this view. However, at 150 ml drinking or 25 g feeding level, WBV and PO increased with time after drinking or feeding. Such changes may be associated with an increase in the relative water intake to feed. Water intake was relatively excessive to feed intake at 150 ml drinking or 25 g feeding level, subsequent to induce an increased urine

production. In colostomised hen, OKUMURA *et al.* (1977) and VAN KAMPEN (1981) showed that the increased water intake increased urine production and did not change water content in faeces, indicating that excessive water from alimentary tract was excreted from kidney. It was noticed that watery stools were excreted 6 times for 25 g feeding or 150 ml drinking level until 15.30 h, while not found for 75 g feeding or 50 ml drinking level. The increases in WBV and PO with time at 25 g feeding and 150 ml drinking level may indicate that the reduced WBV and PO due to relatively excessive water intake recovers because of an increased urine production.

In conclusion, WBV and PO increased with feed intake. However, their changes with time after feeding were related to a water/feed.

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ブロイラーの血液粘度と血漿浸透圧に及ぼす飼料摂取量 と飲水量の影響

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高温曝露による血液粘度の低下の原因を究明するために本研究では、ブロイラーの全血粘度(WBV)に及ぼす飼料摂取量と飲水量の影響について検討した。実験1では、8時に1羽当たり25、50または75gの飼料をそれぞれ8羽ずつに給与した。飼料摂取後、9時に1羽当たり100mlの水を強制的に給与した。実験2では、8時に1羽当たり50gの飼料を摂取させ、9時に50または150mlの水をそれぞれ8羽ずつに強制的に給与した。WBV及び血漿浸透圧(PO)は、飼料摂取量の増加に伴い増加したが、その後、経時的に低下した。ただし、25gでのPOは逆に経時的に増加した。血漿蛋白濃度(PPC)は、25gに比べ50及び75gで有意に($P<0.05$)高くなっ

た。ヘマトクリット(HCT)及び血漿粘度(PV)は、飼料摂取量間に有意差は認められなかった。PPC、HCT及びPVは、飲水量間に有意差は認められなかった。9時半の値で、POは、飲水量50mlに比べ150mlで有意に($P<0.05$)低かった。また、WBV及びPOは、50mlで経時的に低下したが、150mlでは逆に増加した。以上のように、WBV及びPOは飼料摂取量の増加に伴い増加し、その経時的な変化は飼水比と関係していることが分かった。

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