# Effects of Glucose in Drinking Water on the Changes in Whole Blood Viscosity and Plasma Osmolality of Broiler Chickens During High Temperature Exposure

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**ABSTRACT** This study was conducted to elucidate the influence of glucose in drinking water on whole blood viscosity and plasma osmolality of broilers during high temperature exposure. Two groups of birds, which had *ad libitum* access to either a 4% glucose-water solution (Group G) or tap water (Group W), were exposed simultaneously to 30 C from 0300 h for 12 h each day for 3 d. During the experimental period, Group G birds had greater metabolic energy intake and body weight gain than Group W. Hematocrit and whole blood viscosity decreased significantly at 30 C compared to controls at 20 C in Group W, whereas, in Group G, no changes were found for these two variables. Plasma osmolality also decreased at 30 C compared to 20 C in Group W, whereas no change was noted in this variable in Group G. However, at 20 C, plasma osmolality was significantly higher in Group W than in Group G, but no difference was observed between the two groups at 30 C. Plasma protein concentration decreased during exposure to 30 C in both groups, but the decrease tended to be greater in Group W than in Group G. These results suggest that glucose intake may alleviate the influence of heat stress on whole blood viscosity and plasma osmolality.

(*Key words*: glucose intake, blood viscosity, plasma osmolality, high ambient temperature, broiler)

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## INTRODUCTION

During periods of high temperature, it has been found that broilers that consumed a 4% glucose-water solution *ad libitum* from 35 d of age, had significantly lower mortality due to heat stress and higher live weight gain than those birds that received tap water (Iwasaki *et al.*, 1997). This result suggests the possibility for glucose application in the broiler industry for reducing economic losses due to heat exposure. However, the mechanism of the glucose effect remains a question. Thaxton *et al.* (1974) reported that oral administration of glucose increased the body temperature of neonatal chickens that were exposed to 21 C and suggested that carbohydrate metabolism is involved in the physiological regulation of body temperature.

Glucose intake may influence blood viscosity, because blood is not only a medium for transporting nutrients, metabolic waste products, and gases, around the body, but also plays an important role in the diffusion of body heat. Zhou *et al.* (1997b) found that whole blood viscosity (WBV) of broilers decreased significantly when they were exposed to a high ambient temperature. The decrease in WBV may be advantageous in reducing peripheral resistance and the load on heart, and increasing tissue perfusion and circulatory distribution, including the blood supply to heat exchange surfaces. Thermal conductivity of skin increases linearly with rate of blood flow in skin (Ohara, 1981).

The objective of the present study, therefore, was to determine the influence of glucose on WBV and plasma osmolality of broilers to help understand the mechanism by which glucose reduces the mortality of broilers during periods of elevated temperature.

## MATERIALS AND METHODS

Sixteen commercial male broilers (Cobb) were used in this study. Before the experiment, the birds were reared in an open floor house according to Cobb Broiler Management Manual (Matsusaka Farm Co. Ltd., 1994) with 24 h light/d. The birds were transferred into individual cages (45 × 45 × 45 cm) placed in a

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**Abbreviation Key:** HCT = hematocrit; PO = plasma osmolality; PPC = plasma protein concentration; PV = plasma viscosity; WBV = whole blood viscosity.

**TABLE 1. The changes in feed, water, and metabolic energy intake in the broilers receiving tap water (Group W) and those receiving 4% glucose water solution (Group G)[1]**

| | Cycling ambient temperature | | | |
|---|---|---|---|---|
| | 20–20 C | 20–30 C | 20–30 C | 20–20 C |
| Variable | 50 d | 51 d | 53 d | 54 d |
| Feed intake, g/d | | | | |
| Group W | 182.0 ± 10.0[a] | 130.0 ± 10.2[b] | 178.8 ± 12.6[a] | 185.0 ± 9.7[a] |
| Group G | 175.7 ± 3.7[a] | 135.7 ± 3.7[b] | 168.6 ± 2.6[a] | 180.0 ± 8.7[a] |
| Water intake, g/d | | | | |
| Group W | 293.8 ± 8.2[a] | 352.5 ± 28.5[a] | 408.8 ± 29.1[b] | 300.0 ± 20.9[a] |
| Group G | 298.6 ± 17.5[a] | 418.6 ± 41.2[b] | 500.0 ± 41.9[c] | 357.1 ± 37.8[ab] |
| Metabolic energy intake, kcal/d | | | | |
| Group W | 600.0 ± 35.9[a] | 431.2 ± 36.6[b] | 570.3 ± 45.8[a] | 607.3 ± 35.4[a] |
| Group G | 609.8 ± 12.0[a] | 495.8 ± 12.0[b] | 613.2 ± 13.3[a] | 631.4 ± 31.4[a] |
| BW, g | | | | |
| Group W | 3,175 ± 56[a] | | | 3,430 ± 62[b] |
| Group G | 3,180 ± 65[a] | | | 3,490 ± 55[b] |

[a–c]Means within the same row with no common superscript differ significantly ($P < 0.05$).

[1]Mean ± SE (n = 8).

temperature-controlled room at 20 C ambient temperature at 47 d of age. The birds received for *ad libitum* consumption, a grower mash (ME, 3,250 kcal/kg; CP, 180 g/kg; Itochu Feed Mills Co., Ltd). One half of the birds (Group W) consumed tap water *ad libitum*, and the other half (Group G) consumed a 4% glucose-water solution *ad libitum* from 48 d of age.

Both groups of birds were subjected simultaneously to heat exposure and blood sampling as shown in Figure 1; that is, the ambient temperature of the birds was maintained at 20 C at 50 and 54 d of age, whereas temperature was cycled at 51, 52, and 53 d of age. The pattern of cycling temperature was exposure to 30 C from 0300 to 1500 h and to 20 C from 1500 to 0300 h. Blood sampling was conducted from 1445 to 1500 h at 50, 51, 53, and 54 d of age.

Approximately 1.5 mL of blood was obtained *via* ulnar vein puncture using a syringe containing a drop of heparin solution[2] (1,000 IU heparin/mL) each bird each time. Hematocrit value (HCT) was determined using microhematocrit capillary tubes[3] by centrifuging for 5 min at 12,000 rpm (Campbell, 1995); WBV was measured using a Cannon-Manning Semimicroviscometer[4] as described by Zhou *et al.* (1997b). Plasma was obtained by centrifuging the blood for 15 min at 3,500 rpm after WBV was measured. Plasma viscosity (PV) was measured by the same method as WBV. Plasma protein concentration (PPC) was measured by a clinical protein meter.[5] Plasma osmolality (PO) was determined using a semi-micro osmometer.[6]

The feeders and waterers were weighed at 1500 h each day to determine daily feed and water intake. Metabolic energy intake was calculated from feed and glucose intake. Body weight was measured at 1500 h at 50 and 54 d of age. Thus, live weight gains for 5 d during the experimental treatment period were obtained.

A paired *t* test was used to determine the statistical significance between the means within each group. An unpaired *t* test was used to evaluate the significance between the two groups at the same blood sampling point.

## RESULTS

Mean live weight gains for 5 d during the experimental period were 253 g in Group W and 308 g in Group G ($P < 0.05$). The changes in feed, water, metabolic energy intake, and BW are shown in Table 1. Feed and metabolic energy intake decreased significantly during the 1st 20–30 C cycle period compared with during 20–20 C or the 3rd 20–30 C in both experimental groups. Feed intake tended to be lower in Group G than in

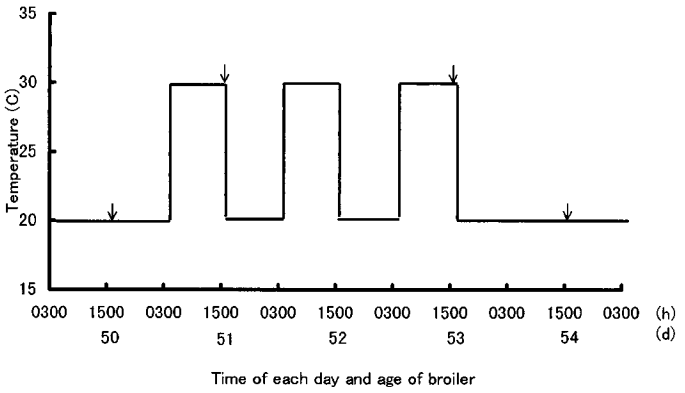


**FIGURE 1.** Schematic program of ambient temperature and blood sampling. ↓ represents blood sampling.

[2]Novo Heparin, Marion Mereru Dau Co., Ltd., Osaka, Japan.
[3]Terumo VC-H075H, Terumo Co., Ltd., Tokyo, Japan.
[4]150, Kusano Scientific Instrument MFG Co., Ltd., Tokyo, Japan.
[5]T2-Se, Atago Co., Ltd., Tokyo, Japan.
[6]Knauer, KG Dr. Herbert Knauer & Co., GmbH, Berlin, Germany.

**TABLE 2. The changes in hematocrit (HCT), whole blood viscosity (WBV), plasma viscosity (PV), plasma protein concentration (PPC), and plasma osmolality (PO) in the broilers receiving tap water (Group W) and those receiving 4% glucose water solution (Group G)[1]**

| | Cycling ambient temperature | | | |
|---|---|---|---|---|
| | 20–20 C | 20–30 C | 20–30 C | 20–20 C |
| Variable | 50 d | 51 d | 53 d | 54 d |
| HCT, % | | | | |
| Group W | 32.2 ± 1.0[a] | 30.9 ± 0.9[b] | 31.8 ± 0.8[a] | 32.0 ± 0.9[ab] |
| Group G | 32.0 ± 1.1[a] | 31.6 ± 1.1[ab] | 31.8 ± 1.2[ab] | 40.8 ± 1.3[b] |
| WBV, cp | | | | |
| Group W | 2.474 ± 0.096[a] | 2.353 ± 0.094[b] | 2.450 ± 0.076[ab] | 2.497 ± 0.150[ab] |
| Group G | 2.430 ± 0.114 | 2.426 ± 0.104 | 2.438 ± 0.113 | 2.366 ± 0.107 |
| PV, cp | | | | |
| Group W | 0.942 ± 0.012 | 0.939 ± 0.008 | 0.934 ± 0.008 | 0.930 ± 0.008 |
| Group G | 0.961 ± 0.006 | 0.959 ± 0.009 | 0.948 ± 0.007 | 0.939 ± 0.007 |
| PPC, g/100 mL | | | | |
| Group W | 3.5 ± 0.1[a] | 3.3 ± 0.1[b] | 3.2 ± 0.1[b] | 3.3 ± 0.1[ab] |
| Group G | 3.5 ± 0.1[a] | 3.4 ± 0.1[b] | 3.3 ± 0.1[bc] | 3.2 ± 0.1[c] |
| PO, mOsm/kg $H_2O$ | | | | |
| Group W | 325.4 ± 2.1[ax] | 312.8 ± 2.2[b] | 312.8 ± 1.4[b] | 321.6 ± 1.5[ax] |
| Group G | 315.9 ± 2.7[y] | 312.4 ± 1.4 | 310.9 ± 1.1 | 313.1 ± 2.0[y] |

[a–c]Means within the same row with no common superscript differ significantly ($P < 0.05$).

[x,y]For each parameter, means for W and G with no common superscript differ significantly ($P < 0.05$).

[1]Mean ± SE (n = 8).

Group W each day, whereas metabolic energy intake tended to be higher due to consumption of the glucose water; however, there were no significant differences between the two groups for these variables. Water intake increased significantly during 20–30 C cycle period in both groups but was not significantly higher in Group G than in Group W.

The changes in HCT, WBV, PV, PPC, and PO are shown in Table 2. In Group W, HCT and WBV decreased significantly at the first exposure to 30 C compared to 20 C (at 50 and 54 d of age) or at the third exposure to 30 C; whereas in Group G, no changes were found in HCT and WBV. In addition, there were no differences in HCT and WBV between Groups W and G on any day. No difference in PV was observed between blood samples within each group or between the two groups at the same blood sampling point. The PPC decreased significantly in both groups during exposure to 30 C; its recovery was not observed, even though ambient temperature returned to constant a 20 C at 54 d. There was also no difference in PPC between the two experimental groups. In Group W, PO was markedly lower during exposure to 30 C than during exposure to 20 C, but no change was found in Group G. At 20 C, the PO was significantly higher in Group W than in Group G, but no difference was found between the two groups at 30 C.

## DISCUSSION

That the live weight gain was greater in Group G than in Group W during experimental period agrees with the results obtained by Iwasaki *et al.* (1997). The increased weight gain may be due to the numerically greater metabolic energy intake obtained by drinking the glucose-water solution in Group G (Table 1). Previously, Thaxton and Parkhurst (1976) had reported that the newly hatched broilers, which received 10% sucrose-water solution prior to the placement of feed, exhibited numerically greater body weights and lower feed conversion ratios than birds that received only water prior to feed. Present results confirm that a readily available energy substrate may improve broiler performance.

The effect of glucose may be involved not only in improving performance, but also in thermoregulation. During high ambient temperature, birds that received a glucose-water solution exhibited lower rectal temperatures than those birds that received only water (Iwasaki *et al.*, 1998). In addition, Iwasaki *et al.* (1997) also observed that there was lower mortality from heat exposure in birds that consumed a glucose-water solution than in those that received only water during heat exposure. These results indicate that thermoregulation may function more efficiently in the birds drinking glucose-water solution than in birds drinking tap water under high ambient temperature, because broiler mortality attributable to heat stress appears to be caused by a loss in thermoregulatory ability (Zhou *et al.*, 1997a). However, further investigation is necessary to determine the influence of glucose on the thermoregulatory responses of broiler chickens.

In the present study, the decreases in HCT (Whittow *et al.*, 1964; Deaton *et al.*, 1969; Kubena *et al.*, 1972; Vanhooser *et al.*, 1995) and WBV (Zhou *et al.*, 1997b), which occurred when the birds were exposed to high

ambient temperature, were also found in Group W. These changes are induced by blood volume expansion due to water coming from interstitial space during an acute heat exposure (Zhou and Yamamoto, 1998). However, no changes were noted in these two parameters in Group G. Plasma osmolality, which also appeared to decrease during high temperature exposure in Group W as observed by Olsson and Dahlborn (1989), did not change in Group G. However, Group G birds had significantly lower PO at 20 C than Group W. This result suggests that drinking glucose-water solution decreases the base level of PO. During heat exposure, although PPC also decreased in both groups of this study, and previously (Deaton *et al.*, 1969; Donkoh, 1989), the level of PPC tended to be lower in Group W than in Group G. These results suggest that glucose intake from drinking water alleviates the influence of high ambient temperature on PV, PO, and PPC, but does not cause WBV to decrease significantly during heat exposure, as previously expected.

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