

Title	Evaluation of drinking water intake, feed water intake and total water intake in dry and lactating cows fed silages
Author(s)	Kume, S.; Nonaka, K.; Oshita, T.; Kozakai, T.
Citation	Livestock Science (2010), 128(1-3): 46-51
Issue Date	2010-03
URL	http://hdl.handle.net/2433/102278
Right	c 2009 Elsevier B.V. All rights reserved.
Type	Journal Article
Textversion	author

WATER INTAKE IN DAIRY COWS

Evaluation of drinking water intake, feed water intake and total water intake in dry and lactating cows fed silages

S. Kume^{a, *}, K. Nonaka^b, T. Oshita^c, and T. Kozakai^c

^a Graduate School of Agriculture, Kyoto University, Kyoto 606-8502, Japan

^b Natl. Inst. Livestock and Grassland Sci., Nishinasuno 329-2793, Japan

^c Natl. Agric.Res.Cent. for Hokkaido Reg., Sapporo 062-8555, Japan

ABSTRACT: Data of 46 water balance measurements were collected from dry and lactating Holstein cows in the controlled climatic chamber, which maintained at 20°C and 60% relative humidity, to evaluate between drinking water intake (DWI), feed water intake (FWI), total water intake (TWI) and some variables in cows. Orchardgrass silage, alfalfa silage and corn silage were offered in dry cows, and alfalfa or orchardgrass silage and concentrates were given as a TMR in ratio of 60:40 in lactating cows. DMI and milk production were highly related to DWI and TWI of lactating cows. DWI in dry and lactating cows increased and FWI decreased as dietary DM increased, but there was a very weak correlation between dietary DM and TWI. In both dry and lactating cows, positive correlations were obtained between dietary CP or K and TWI, especially highly correlations between dietary K and TWI. There were strong positive correlations between N intake, K intake or urine volume and TWI rather than DWI in dry and lactating cows. These results suggest that dry and lactating cows accelerate DWI to excrete large amounts of K or N into urine in excess of their needs, but

* Corresponding author. Tel: +81-75-7536325. Fax: +81-75-7536345.

E-mail address: kume@kais.kyoto-u.ac.jp.

22 TWI is more suitable to evaluate the effects of dietary CP or K on water intake and urine
23 volume in dairy cows.

24 **Key Words :** dry cows, lactating cows, nitrogen, potassium, urine volume, water intake

25

26

INTRODUCTION

27 Water is the most important nutrient for dairy cows. The sum of drinking water intake
28 (DWI) and ingestion of water contained in feed (FWI) is the total water intake (TWI), because
29 metabolic water is an insignificant source compared with DWI and FWI (NRC, 2001). High
30 producing cows require large amounts of water as well as appropriate amounts of energy,
31 protein and minerals to support high milk yield. The importance of high quality roughage,
32 especially high quality silages such as alfalfa and corn silage, has been recognized for
33 maximal milk yield, and silage is an important water source for dairy cows.

34 Loss of water from the body occurs through milk production, urine and fecal excretion,
35 sweat and vapor loss from lungs (NRC, 2001). A sufficient supply of water is essential to
36 avoid negative effects on animal health, performance and welfare (Murphy, 1992; Meyer et
37 al., 2004), and 25 and 50% restriction of drinking water relative to ad libitum intake decreased
38 feed intake and milk yield in dairy cows (Steiger Burgos et al., 2001). However, a surplus
39 supply of water may lead to disturb a constant extracellular fluid volume and osmolality and
40 increase urine volume in dairy cows. The decreasing urine production from dairy cows is
41 needed for the optimum cow management in dairy farms, because environmental pollution
42 from livestock wastes has a serious problem in Japanese dairy farming. Urinary water
43 excretion was positively related to water availability, amount of water absorbed from the
44 intestinal tract and urinary N and K excretion in cows (Murphy, 1992). In the previous paper
45 (Kume et al., 2008a), the urine volume in cows increased with the increasing urinary
46 excretion of K and N, and the increase of urine production may be due to the maintenance of

47 urine or plasma osmolality. Although the optimal control of water intake in dairy cows is
48 useful for decreasing urine production and maintaining high milk production, few reports
49 have been demonstrated the relationships between water intake, dietary nutrient contents,
50 nutrient intake and urine production, respectively.

51 The objective of this study was conducted to clarify the relationships between TWI, DWI,
52 FWI and some variables such as nutrient contents, nutrient intake and urine production in dry
53 and lactating cows in the controlled climatic chamber, which maintained at 20°C and 60%
54 relative humidity.

55

56 **MATERIAL AND METHODS**

57 This research was approved by the guide for the care and use of animals in National
58 Agricultural Research Center for Hokkaido Region. The experiment was conducted as
59 previously described (Kume et al., 2004, 2008a, 2008b; Kojima et al., 2005). Data of 30 and
60 16 balance measurements were collected from dry and lactating Holstein cows, respectively.
61 Orchardgrass silage, alfalfa silage, corn silage, orchardgrass plus alfalfa silage, orchardgrass
62 plus corn silage or alfalfa plus corn silage were offered to meet the TDN requirements of dry
63 cows (Agriculture, Forestry, and Fisheries Research Council Secretariat, 1994). Because of
64 the low CP contents, 9 % of soybean meal was supplemented for the dry cows fed corn silage.
65 In 8 lactating cows, orchardgrass silage or alfalfa silage diets were offered in the switch back
66 trials. Roughage and concentrates were given as a TMR in ratio of 60:40 to meet the TDN
67 requirements of the cows.

68 The trials were performed for 14 days in dry and lactating cows after an initial adaptation
69 period of 5 to 7 days. The cows were fed equal amounts of feed at 08:00 and 16:00 h and
70 were given free access to water. The lactating cows were milked twice daily, and milk
71 weights were recorded. Cows were housed in the individual pens for 7 to 10 days during the

72 feed adjustment period, followed by the 4 to 7 day collection period from 10:30 to 10:30 h
73 daily in the metabolic chamber. The metabolic chamber was maintained at 20°C and 60%
74 relative humidity. Feed refusals and drinking water intake were recorded daily, and drinking
75 water intake was measured by the water meter. Feces and urine from each cow were
76 separately collected and weighed daily during the collection period.

77 Samples of feces, feed and feed refusals were oven-dried for 48 hours at 60°C and ground
78 to pass a 1-mm screen. The DM contents of feces, feed and feed refusals were determined by
79 oven drying at 100°C for 2 hours, and then water intake from feed and fecal water excretion
80 in each cow were calculated. The CP, ADF, NDF and K contents of feces, feed and feed
81 refusals were determined as previously described (Kume et al., 2001).

82 Relationships between TWI, DWI, FWI and other variables in dry and lactating cows
83 were examined by correlation and regression analyses of SAS (1997). Significance was
84 declared at $P < 0.05$.

85

86

RESULTS

87 Mean TWI in dry cows was 30.3 kg/day, consisted of 16.0kg (52.8% of TWI) from DWI
88 and 14.3kg (47.2% of TWI) from FWI, whereas mean TWI in lactating cows was 98.4kg/day,
89 consisted of 77.6kg (78.9% of TWI) of DWI and 20.8kg (21.1% of TWI) from FWI (Tables 1
90 and 2). Mean urine volume and fecal water excretion in dry cows were 12.8 and 12.4kg/day,
91 respectively, and those in lactating cows were 21.9 and 35.2kg/day, respectively. Mean milk
92 yield in lactating cows was 29.5kg/day, ranging from 21.9 to 35.3kg/day. Nutrient contents
93 and nutrient intake in dry and lactating cows varied.

94 In dry cows, dietary DM ($P < 0.05$), CP ($P < 0.001$), ADF ($P < 0.001$), K ($P < 0.001$), DMI
95 ($P < 0.001$), N intake ($P < 0.001$), ADF intake ($P < 0.001$), NDF intake ($P < 0.01$), K intake
96 ($P < 0.001$), urine volume ($P < 0.001$), fecal water ($P < 0.001$) and DWI ($P < 0.001$) were

97 positively correlated to TWI, but FWI ($P<0.001$) was negatively correlated to TWI. Dietary
 98 DM ($P<0.001$), CP ($P<0.01$), K ($P<0.001$), N intake ($P<0.01$), K intake ($P<0.001$) and urine
 99 volume ($P<0.001$) were positively correlated to DWI. Dietary ADF ($P<0.05$), NDF ($P<0.01$),
 100 ADF intake ($P<0.01$), NDF intake ($P<0.01$) and BW ($P<0.01$) were positively correlated to
 101 FWI, but dietary DM ($P<0.001$) and K ($P<0.05$) were negatively correlated to FWI.

102 In lactating cows, Dietary DM ($P<0.05$), CP ($P<0.05$), K ($P<0.001$), DMI ($P<0.001$), N
 103 intake ($P<0.001$), ADF intake ($P<0.01$), K intake ($P<0.001$), milk yield ($P<0.01$), urine
 104 volume ($P<0.001$) and DWI ($P<0.001$) were positively correlated to TWI, but dietary NDF
 105 ($P<0.01$) was negatively correlated to TWI. Dietary DM ($P<0.001$), K ($P<0.05$), DMI
 106 ($P<0.001$), N intake ($P<0.01$), ADF intake ($P<0.01$), K intake ($P<0.001$), milk yield ($P<0.01$)
 107 and urine volume ($P<0.01$) were positively correlated to DWI, but dietary NDF ($P<0.05$) was
 108 negatively correlated to DWI. Only dietary DM ($P<0.001$) was negatively correlated to FWI.

109 There were strong correlations between dietary DM and DWI or FWI in dry and
 110 lactating cows, but a weak correlation was obtained between dietary DM and TWI (Figure1).
 111 The regression equations of dietary DM (X_{DM}) on DWI in dry cows (Y_{DDW}), FWI in dry cows
 112 (Y_{DFW}), DWI in lactating cows (Y_{LDW}) and FWI in lactating cows (Y_{LFW}) were as follows.

$$113 \quad Y_{DDW} = 0.915(\pm 0.119)^{***} X_{DM} - 18.8(\pm 4.7)^{***} \quad (R^2=0.67, \quad ***P<0.001)$$

$$114 \quad Y_{DFW} = -0.572(\pm 0.056)^{***} X_{DM} + 36.1(\pm 2.2)^{***} \quad (R^2=0.78, \quad ***P<0.001)$$

$$115 \quad Y_{LDW} = 1.58(\pm 0.29)^{***} X_{DM} - 3.4(\pm 14.9) \quad (R^2=0.66, \quad ***P<0.001)$$

$$116 \quad Y_{LFW} = -0.764(\pm 0.078)^{***} X_{DM} + 59.9(\pm 4.1)^{***} \quad (R^2=0.86, \quad ***P<0.001)$$

117 There were strong correlations between dietary K or CP and TWI in dry cows, and there
 118 were positive relationship between dietary K or CP and TWI in lactating cows (Figure 2). The
 119 regression equations of dietary K (X_K) on TWI in dry cows (Y_{DTW}) and TWI in lactating cows
 120 (Y_{LTW}) and dietary CP (X_{CP}) on TWI in dry cows (Y_{DTW}) and TWI in lactating cows (Y_{LTW})
 121 were as follows.

122 $Y_{DTW} = 7.43(\pm 1.27)^{***} X_K + 12.8(\pm 3.2)^{***} (R^2=0.53, ***P<0.001)$

123 $Y_{LTW} = 36.3(\pm 8.1)^{***} X_K + 27.4(\pm 16.0) (R^2=0.56, ***P<0.001)$

124 $Y_{DTW} = 1.51(\pm 0.36)^{***} X_{CP} + 7.60(\pm 5.63) (R^2=0.36, ***P<0.001)$

125 $Y_{LTW} = 4.15(\pm 1.68)^* X_{CP} + 29.4(\pm 28.1) (R^2=0.26, *P<0.05)$

126 There were strong positive correlations between DMI, N intake, K intake or urine
127 volume and TWI in dry and lactating cows (Figure 3). The regression equations of DMI
128 (X_{DMI}), N intake (X_{NI}), K intake (X_{KI}) and urine volume (X_{UV}) on TWI in dry cows (Y_{DTW})
129 and TWI in lactating cows (Y_{LTW}) were as follows.

130 $Y_{DTW} = 5.91(\pm 1.30)^{***} X_{DMI} - 15.2(\pm 10.1) (R^2=0.40, ***P<0.001)$

131 $Y_{LTW} = 6.24(\pm 0.67)^{***} X_{DMI} - 31.0(\pm 13.9)^* (R^2=0.86, ***P<0.001)$

132 $Y_{DTW} = 0.140(\pm 0.020)^{***} X_{NI} + 4.28(\pm 3.78) (R^2=0.63, ***P<0.001)$

133 $Y_{LTW} = 0.129(\pm 0.018)^{***} X_{NI} + 26.4(\pm 10.3)^* (R^2=0.50, ***P<0.001)$

134 $Y_{DTW} = 0.105(\pm 0.011)^{***} X_{KI} + 11.1(\pm 2.3)^{***} (R^2=0.74, ***P<0.001)$

135 $Y_{LTW} = 0.141(\pm 0.015)^{***} X_K + 40.6(\pm 6.5)^{***} (R^2=0.85, ***P<0.001)$

136 $Y_{DTW} = 1.66(\pm 0.18)^{***} X_{UV} + 8.98(\pm 2.45)^{***} (R^2=0.75, ***P<0.001)$

137 $Y_{LTW} = 1.72(\pm 0.26)^{***} X_{UV} + 60.6(\pm 6.0)^{***} (R^2=0.74, ***P<0.001)$

138

139 DISCUSSION

140 Several factors affect amounts of DWI or TWI in dairy cows, and DMI, milk yield,
141 environmental temperatures and dietary DM, CP, Na and fiber were included in the factors
142 (NRC, 2001). Environmental temperature and relative humidity are important factors for
143 water intake in dairy cows (Murphy, 1992; NRC, 2001; Meyer et al., 2004; Cardot et al.,
144 2008), and water is an especially important nutrient during heat stress. Because climatic
145 condition was controlled at 20°C and 60% relative humidity in this study, data obtained may
146 be not affected by environmental temperature and humidity.

147 DMI and milk production were highly related to DWI and TWI of lactating cows in this
148 study. Milk production is closely correlated to DMI or water intake (Murphy, 1992; Kramer et
149 al., 2008). With 33-35 kg/day of milk production, DWI and TWI per kg of milk produced
150 were 2.0-2.7 and 2.6-3.0 kg, respectively, but those with lower milk production, less than
151 26kg/day, were 2.6-3.0 and 3.3-4.2 kg, respectively (NRC, 2001). In this study, increasing
152 milk yield increased DWI and TWI in lactating cows, and mean DWI and TWI per kg of milk
153 produced in cows were 2.6 and 3.3 kg, respectively. According to 29.5 kg of averaged milk
154 yield in this study, these figures were considered to be appropriate, compared to the data in
155 NRC (2001). In dry cows, increasing DMI increased TWI, but DWI was not affected by
156 increasing DMI, which suggested that feed water was a predominant water source for dry
157 cows fed silages and FWI influenced DWI.

158 Dietary DM content is one of the major factors affecting DWI in dairy cows (NRC, 2001).
159 Increasing DM percentage of the diet increased DWI in dairy cows but decreased TWI
160 (Paquay, et al., 1970; Murphy, 1992; Dahlborn, et al., 1998; Dewhurst et al. 1998), which
161 indicated that the increased DWI was not able to compensate for the reduction of FWI. TWI
162 in lactating cows were not affected by increasing dietary DM, but DWI in dry cows increased
163 about 7L/day and TWI decreased about 15L/day as ration moisture dropped from 70 to 40%
164 (Holter and Urban 1992). In this study, DWI in dry and lactating cows increased and FWI
165 decreased as dietary DM increased, but clear relationships between dietary DM and TWI were
166 not obtained in dry and lactating cows.

167 TWI and FWI in dry cows increased as dietary ADF increased in this study, but negative
168 correlation were obtained between dietary NDF and TWI or DWI in lactating cows.
169 Increasing ADF or NDF intake increased TWI and FWI in dry cows, and increasing ADF
170 intake increased TWI and DWI in lactating cows. Because increasing forage in the diet might
171 increase water requirements by increasing water loss in feces and urine (Dahlborn, et al.,

172 1998; NRC, 2001) and high NDF diet might decrease TWI in lactating cows (Dado and Allen,
173 1995), dietary ADF or NDF may be a factor affecting TWI in dairy cows fed silages.

174 In both dry and lactating cows in this study, significant correlations were obtained between
175 dietary CP or K and TWI, especially highly correlations between dietary K and TWI. Dietary
176 K was correlated to DWI in dry and lactating cows, and dietary CP is correlated to DWI in
177 dry cows. Also, N intake, K intake or urine volume in dry and lactating cows were more
178 related to TWI rather than DWI, and the increasing rates of N intake, K intake and urine
179 volume on TWI were almost similar between dry and lactating cows. These results suggest
180 that dry and lactating cows accelerate DWI to excrete large amounts of K or N into urine in
181 excess of their needs, but TWI is more suitable to evaluate the effects of dietary CP or K on
182 water intake and urine volume in dairy cows.

183 Delaquis and Block (1995) reported that apparent absorption of water and urine volume in
184 dairy cows was increased by a higher dietary cation-anion difference defined as
185 milliequivalents of (Na+K-Cl-S)/kg of DM. Bannink et al. (1999) suggested that urine volume
186 is determined mainly by the effect of Na, K and N on urine osmolality. In the previous paper
187 (Kume et al., 2008a), the urine volume in cows was affected by the wide range of water intake
188 and increased as urinary K or N excretion increased, but urine volume was not affected by
189 urinary Na excretion. The diets high in protein appear to stimulate water intake of cows, and
190 then water excess reduced the osmolality of extracellular fluid, resulting in water diuresis and
191 normalization of plasma osmolality (Kohn et al., 2005; Kume et al., 2008a, 2008b). In
192 adjusting the urine osmolality in cows, K played an important role in the formation of
193 concentrated urine at low urinary K excretion, but the concentrating capacity of K at high
194 urinary excretion was almost constant due to the isotonic function of the tubule and the
195 increasing urinary flow in the collecting duct of kidney due to the increase of water intake
196 may be needed to excrete larger quantities of K (Kume et al., 2008a). Paquay et al. (1970)

197 reported that the increase in urinary water loss for dry and lactating cows, especially if the
198 result of given food with a high moisture content, is related to a greater excretion of N and K
199 in urine. Because of maintenance of plasma or urine osmolality, dietary N and K may have
200 large effects on water intake and urine volume in dry and lactating cows fed silages.

201 In practical dairy farming, cows fed alfalfa silage produced more milk than did cows fed
202 grass silage (Hoffman et al., 1998 ; Kume, 2002), but alfalfa with 20% of CP contained high K
203 such as 3.49% in the first cutting (Kume et al., 2001). Corn silage contained 7.1 to 8.2% of
204 CP and 1.2 to 1.3% of K, and feeding corn silage decreased urinary N and K excretion in
205 cows (Kume et al., 2003, 2008a, 2008b). Also, feeding corn silage plus alfalfa silage derived
206 maximal benefit and 5 to 15% reduction in the loss of N to the environment (Dhiman and
207 Satter, 1997). However, the increased K intake in dry cows may raise urine volume and
208 thereby result in increased urinary N excretion according to the path analysis (Kojima et al.
209 2005), and 5 % of KCl supplementation increased urinary N excretion as well as .water intake
210 and urine volume in mice (Murai et al. 2008, in press). Further study is needed to clarify the
211 relationships between water intake, nutrient intake and urine production for cows in the dairy
212 farms to eliminate environmental pollution and obtain maximal benefit.

213

214 **ACKNOWLEDGMENTS**

215 The authors thank S. Naito, S.Nakajima and the staff of the National Agricultural Research
216 Center for Hokkaido Region for technical help and assistance of sample collection.

217

218 **REFERENCES**

219 Agriculture, Forestry, and Fisheries Research Council Secretariat, 1994. Japanese Feeding

220 Standard for Dairy Cattle. p19-24. Chuouchikusankai. Tokyo. Japan.

221 Bannink, A., Valk,A., Van Vuuren, A.M. 1999. Intake and excretion of sodium, potassium,

222 and nitrogen and the effects on urine production by lactating dairy cows. *J.Dairy Sci.* 82,
223 1008-1018.

224 Cardot, V., Le Roux, Y., Jurjanz. 2008. Drinking behavior of lactating dairy cows and
225 prediction of their water intake. *J. Dairy Sci.* 91, 2257-2264.

226 Dadd, R.G., Allen, M.S. 1995. Intake limitations, feeding behavior, and rumen function of
227 cows challenged with rumen fill from dietary fiber or inert bulk. *J. Dairy Sci.* 78,
228 118-133.

229 Dahlborn, K., Akerlind, M., Gustafson, G. 1998. Water intake by dairy cows selected for high
230 or low milk-fat percentage when fed two forage to concentrate ratios with hay or silage.
231 *Swedish J. agric. Res.* 28, 167-176.

232 Dewhurst, R.J., Offer, N.W., Thomas, C. 1998. Factors affecting water intake of lactating
233 dairy cows offered grass silages differing in fermentation and intake characteristics. 1998.
234 *Animal Science.* 66, 543-550.

235 Delaquis, A.M., Block, E. 1995. Dietary cation-anion difference, acid-base status, mineral
236 metabolism, renal function, and milk production of lactating cows. *J.Dairy Sci.* 78,
237 2259-2284.

238 Dhiman, T.R., Satter, L.D. 1997. Yield response of dairy cows fed different proportions
239 alfalfa silage and corn silage. *J.Dairy Sci.* 80, 2069-2082.

240 Hoffman, P.C., Combs, D.K., Casler, M.D., 1998. Performance of lactating dairy cows fed
241 alfalfa silage or perennial ryegrass silage. *J.Dairy Sci.* 81, 162-168.

242 Holter, J.B., Urban, Jr, W.E. 1992. Water partitioning and intake prediction of dry and
243 lactating Holstein cows. *J.Dairy Sci.* 75, 1472-1479.

244 Kohn, R.A., Dinneen, M. Russek-Cohen. 2005. Using blood urea nitrogen to predict nitrogen
245 excretion and efficiency of nitrogen utilization in cattle, sheep, goats, horses, pigs, and
246 rats. *J.Anim.Sci.* 83, 879-889.

247 Kramer, E., Stamer, E., Mahlkow, K., Lüpping, W., Krieter, J. 2008. Relationships between
248 water intake, dry matter intake and daily milk yield on a German research farm. *Livest.*
249 *Sci.* 115, 99-104.

250 Kume, S. 2002. Establishment of profitable dairy farming system on control of methane
251 production in Hokkaido region, In:Takahashi,J. and Young,B.A.(eds) , *Greenhouse*
252 *Gases and Animal Agriculture*, 87-94. Elsevier Science B.V.

253 Kume, S., Nonaka, K., Oshita,T., Kozakai, T, Hirooka, H. 2008a. Effects of urinary excretion
254 of nitrogen, potassium and sodium on urine volume in dairy cows. *Livest. Sci.* 115,
255 28-33.

256 Kume, S., Nonaka, K., Oshita,T., Kozakai, T, Kojima,H. 2004. Potassium excretion of dry,
257 pregnant and lactating cows fed forage. *Nihon Chikusan Gakkaiho* 75, 179-184 (In
258 Japanese, with English abstract).

259 Kume,S., Toharmat,T., Nonaka,K., Oshita,T., Nakui,T., Ternouth, J.H.. 2001. Relationships
260 between crude protein and mineral concentrations in alfalfa and value of alfalfa silage as
261 a mineral source for periparturient cows. *Anim. Feed Sci. Tech.* 93, 157-168.

262 Kume, S., Numata, K., Takeya, Y., Miyagawa, Y., Ikeda, S., Kitagawa, M, Nonaka, K, Oshita,
263 T, Kozakai, T. 2008b. Evaluation of urinary nitrogen excretion from plasma urea
264 nitrogen in dry and lactating cows. *Asian-Aust. J. Anim. Sci.* 21, 1159-1163.

265 Kojima, H., Kume,S., Nonaka,K., Oshita,T., Kozakai,T., Hirooka,H. 2005. Effects of feeding
266 and animal performance on nitrogen, phosphorus and potassium excretion by Holstein
267 cows. *Anim. Sci. J.* 76, 139-145.

268 Meyer, U., Everinghoff, M., Gädeken, D., Flachowsky, G. 2004. Investigation on the water
269 intake of lactating dairy cows. *Livest. Prod. Sci.* 90, 117-121.

270 Murai I, Imanishi S, Sugimoto M, Kume S. 2008. Effects of high potassium chloride
271 supplementation on growth rate and renal function in mice. *Anim. Sci. J.* 79, 243-247.

272 Murai I, Sugimoto M, Ikeda, S., Kume S. Effects of high potassium chloride supplementation
273 on water intake, urine volume and nitrogen balance in mice. *Anim. Sci. J.* (in press)

274 Murphy, M.R., 1992. Water metabolism of dairy cattle. *J.Dairy Sci.* 75, 326-333.

275 National Research Council, 2001. Nutrient requirements of dairy cattle. 7th. rev. ed.
276 Natl.Acad.Sci., Washington,D.C.

277 Paquay, R., De Bafre, R., Lousse, A. 1970. Statistical research on the fate of water in the
278 adult cow. II. The lactating cows. *J. Agric. Sci. (Camb.)*. 75, 251-255.

279 Statistical Analysis System (SAS). 1997. SAS/STAT Software: Changes and Enhancement
280 Through Release 6.12. SAS Institute, Cary, NC.

281 Steiger Burgos, M., Senn, M., Sutter, F., Kreuzer, M., Langhans, W. 2001. Effect of water
282 restriction on feeding and metabolism in dairy cows. *Am. J. Physiol. Regulatory*
283 *Integrative Comp. Physiol.* 280, R418-R427.

284

Table 1.

Correlation between total water intake (TWI)¹, drinking water intake (DWI), feed water intake (FWI) and other variables in dry cows (n=30)

	Mean	SD	Min.	Max.	r		
					TWI	DWI	FWI
Nutrient, % of DM							
DM	38.1	11.0	21.6	58.1	0.40*	0.82***	-0.89***
CP	15.0	3.8	10.6	22.4	0.62***	0.54**	-0.11
ADF	33.6	5.6	21.3	41.8	0.60***	0.22	0.42*
NDF	46.7	7.2	34.0	63.3	0.23	-0.11	0.49**
K	2.35	0.93	1.07	4.04	0.74***	0.79***	-0.39*
Intake							
DM, kg/day	7.7	1.0	6.1	9.7	0.65***	0.29	0.36
N, g/day	186	54	109	309	0.80***	0.54**	0.13
ADF, kg/day	2.62	0.67	1.55	3.78	0.70***	0.26	0.47**
NDF, kg/day	3.64	0.92	2.29	5.78	0.49**	0.09	0.49**
K, g/day	183	77	81	361	0.87***	0.80***	-0.24
Body weight, kg	619	66	515	803	0.13	-0.05	0.46**
Urine volume, kg/day	12.8	4.9	6.7	24.0	0.87***	0.81***	-0.25
Fecal water, kg/day	12.4	3.1	6.4	18.5	0.64***	0.31	0.32
TWI, kg/day	30.3	9.3	14.6	48.1	--	--	--
DWI, kg/day	16.0	12.2	0.3	39.5	0.82***	--	--
FWI, kg/day	14.3	7.1	5.3	33.9	-0.65***	-0.09	--

* P<0.05.

** P<0.01.

*** P<0.001

¹Drinking water intake plus feed water intake.

33
 34
 35
 36
 37
 38
 39
 40
 41
 42
 43
 44
 45
 46
 47
 48
 49
 50
 51
 52
 53
 54
 55
 56
 57
 58
 59
 60
 61
 62
 63
 64
 65
 66

Table 2.
 Correlation between total water intake (TWI)¹, drinking water intake (DWI), feed water intake (FWI) and other variables in lactating cows (n=16)

	Mean	SD	Min.	Max.	r		
					TWI	DWI	FWI
Nutrient, % of DM							
DM	51.2	9.5	38.2	64.7	0.52*	0.83***	-0.93***
CP	16.6	2.0	12.3	18.3	0.55*	0.37	0.21
ADF	26.4	1.9	24.5	32.5	-0.26	-0.22	0.00
NDF	39.4	6.3	31.8	48.4	-0.69**	-0.52*	-0.11
K	1.96	0.32	1.56	2.31	0.77***	0.55*	0.19
Intake							
DM, kg/day	20.7	2.2	17.2	24.1	0.93***	0.83***	-0.16
N, g/day	557	102	387	705	0.89***	0.73**	0.01
ADF, kg/day	5.45	0.63	4.22	6.19	0.68**	0.63**	-0.14
NDF, kg/day	8.10	1.16	6.48	10.27	-0.11	-0.01	-0.19
K, g/day	410	98	268	555	0.93***	0.75***	-0.02
Body weight, kg	609	48	557	703	0.05	0.03	0.03
Milk yield, kg/day	29.5	3.5	21.9	35.3	0.66**	0.62**	-0.18
Urine volume, kg/day	21.9	7.5	11.2	33.2	0.87***	0.73**	-0.02
Fecal water, kg/day	35.2	7.2	22.4	45.4	0.28	0.16	0.15
TWI, kg/day	98.4	14.9	78.1	124.2	--	--	--
DWI, kg/day	77.6	18.1	57.0	110.3	0.91***	--	--
FWI, kg/day	20.8	7.7	12.0	36.4	-0.20	-0.59*	--

* P<0.05.
 ** P<0.01.
 *** P<0.001

¹Drinking water intake plus feed water intake.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23

Figure 1. Relationships between dietary DM contents and total water intake (○), drinking water intake (●) or feed water intake (▲) in dry and lactating cows.

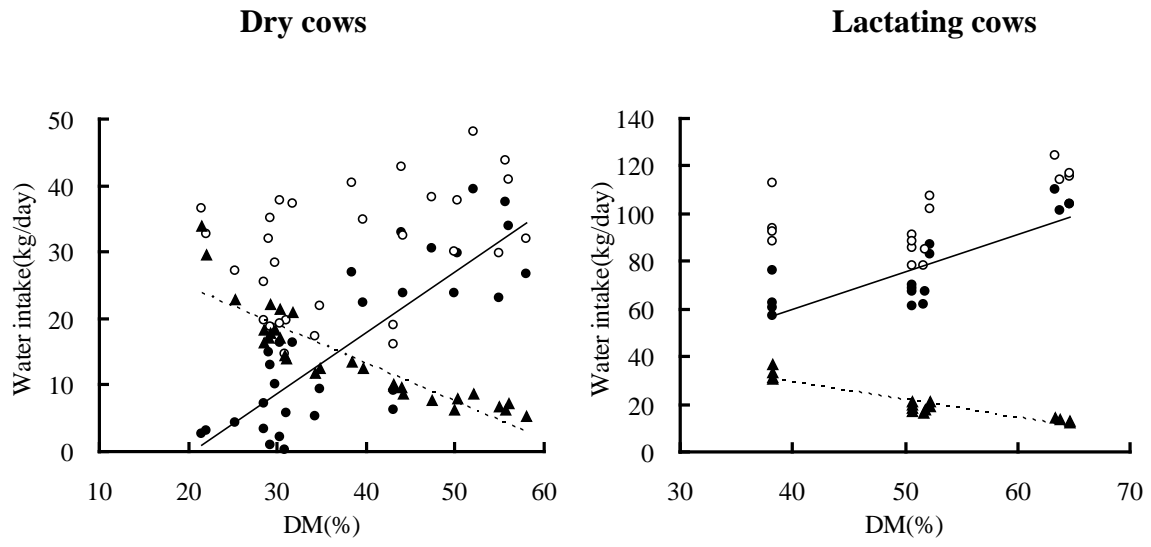
Figure 2. Relationships between dietary CP or K contents and total water intake (○) or drinking water intake (●) in dry and lactating cows.

Figure 3. Relationships between DMI, Urine volume, CP or K intake and total water intake (○) or drinking water intake (●) in dry cows and relationships between DMI, urine volume, CP or K intake and total water intake (□) or drinking water intake (■) in lactating cows.

24

25

26



27

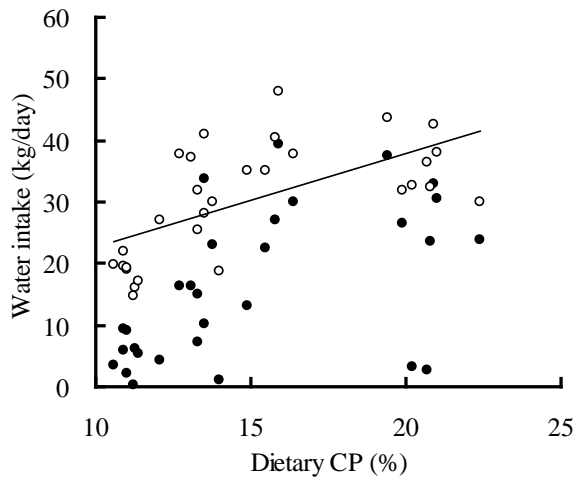
28

Fig.1

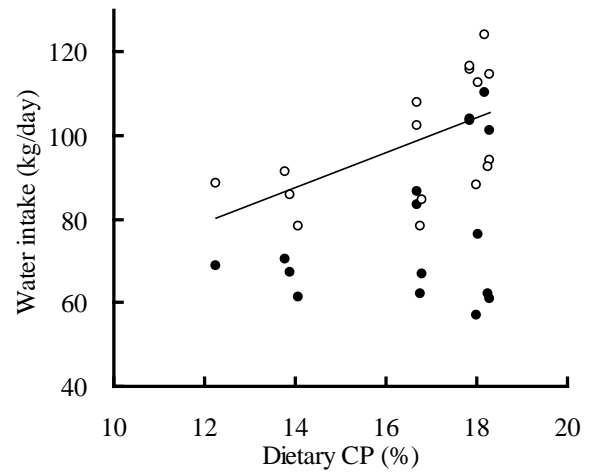
29

30

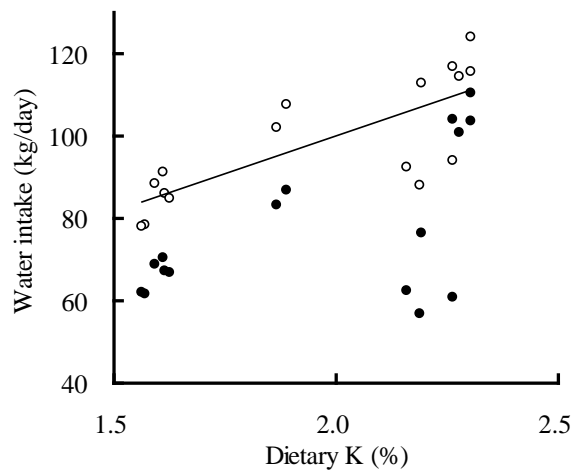
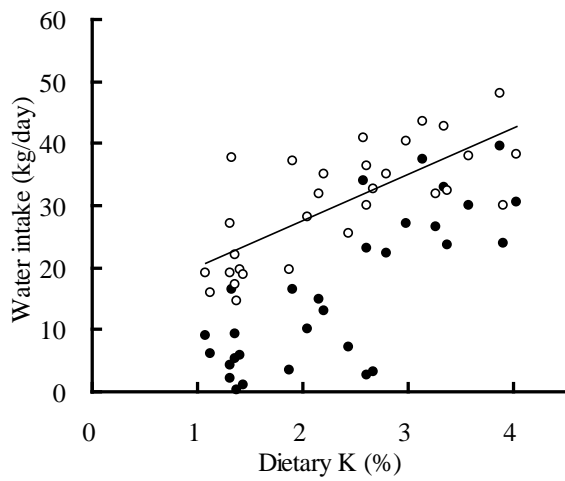
Dry cows



Lactating cows



31



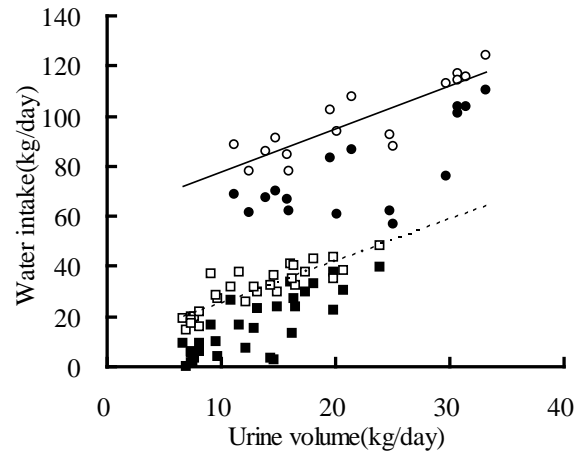
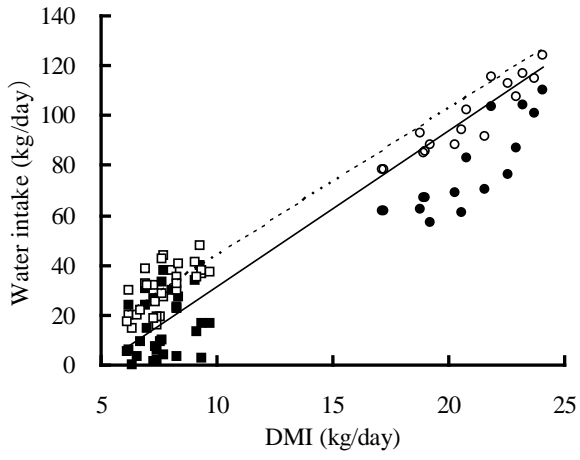
32

33

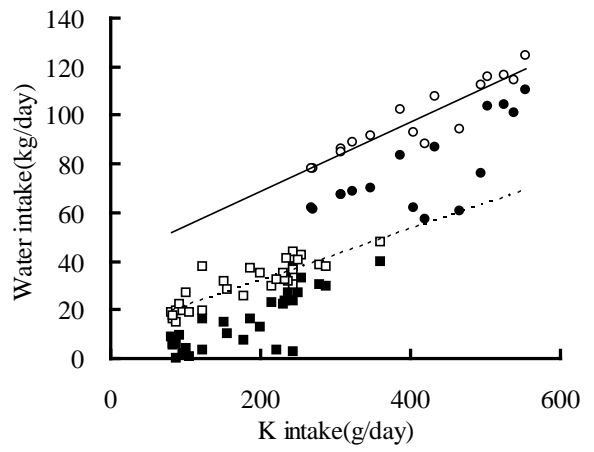
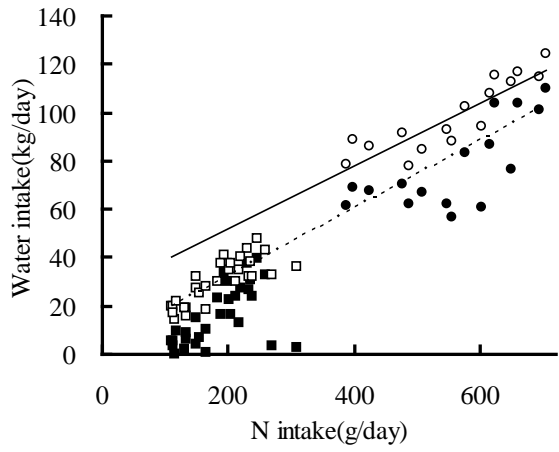
Fig.2

34

35



36



37

38 Fig.3