Effects of Feed Viscosity on Water Excretion in Meat-Turkey Poults

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Introduction

The litter humidity is an important factor that requires to be controlled in the poultry production systems, as litter humidity may affect the health of birds and the carcass quality. This litter humidity depends on litter amounts, temperature, ventilation, and amount of water excreted by birds. The experiment presented here was designed in order to determine how water excretion may be controlled by diet formulation. Most of the dietary factors responsible for water consumption and excretion have been already identified. Those concerning ions such as potassium, sodium and chlorine (Smith et *al.* 1973; Smith and Teeter, 1989) may be readily controlled by diet formulation. Concerning the viscosities produced by water-soluble non-starch polysaccharides (Water-soluble NSP), evidences exist for their responsabilities in water excretion increases (Moran *et al.* 1969; Gohl *et al.* 1978) and growth performance reductions (Choct *et al.* 1992; Bedford and Classen, 1992). However, until now, possibilities for controlling NSP viscosity using diet formulation were not available. This is not really surprising because NSP viscosity determinations in feeds are technically difficult and may be affected by many interactions such as enzyme activities and viscosities due to protein. The other problem concerns the additivity of viscosity determinations. Establishing continuous functions that relate water excretion to feed viscosity may also prove experimentally difficult.

However, all these points require to be solved for controlling water excretion by diet formulation. So, our experiment was focused on the following points: the methodology for viscosity determination in feeds; the additivity of viscosity measurements; the functions relating the water consumption and excretion to the feed parameters including viscosity.

The bird type chosen for this study was meat turkey poult, as the production of these birds is one of the most sensitive to litter humidity.

Metods for Viscosity Determination in Feed Extracts

Potential viscosity

The mainprinciple of this determination is to apply viscosity measurement on extracts obtained under conditions inactivating enzyme activities. The other principle is to measure the viscosity specifically supplied by water-soluble NSP. So, the extraction is done under conditions where proteins do not supply viscosity. Accordingly, the acidic pH used as an inactivating condition is only applied for cereals. For samples of any origin, another extraction procedure is used because, at low pH, for sample containing high amounts of proteins such as legume seeds, a great part of the viscosity may come from proteins. Moreover, it is difficult to obtain acidic pH for mixed diets because of the high amounts of calcium salts. Accordingly, for samples of any origin, inactivation of enzymes is obtained by a prior hot treatment in ethanol: water 80:20.

Measurement in samples of any origin

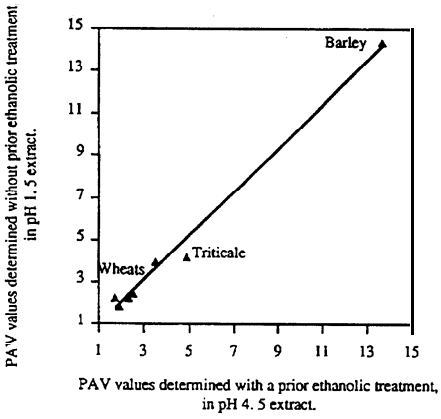
The sample (3.5 g) ground to .5 mm is treated under reflux in 30 ml ethanol: water (80:20) for 1 h, cooled at ambient temperature, let stand for 16 h and centrifuged (5000 g, 15min). The residue is rinsed by centrifugation with ethanol:water (80:20) and then acetone, let stand at ambient temperature for 20 h for drying, and extracted at ambient temperature in 30 ml pH 4.5 .2 M acetate buffer for 1 h under magnetic stirring (300 rpm). The suspension is centrifuged (1000 g, 15 min), the extract is filtrated under vacuum on a nylon filter (5 μm), let stand for 10 to 120 min and measured for its viscosity. The viscosimeter used for this measurement should be sensitive enough for determining the viscosity of water.

The apparatus used in the present experiments was a coaxial cylinder viscosimeter (Rheomat 115A, Contraves) run at ambient temperature (19-23°C) in the decreasing shear rate ranges of 25-800 s^{-1} (for viscosities from .95 to 2 mPa.s), 10-400 s^{-1} (from 2 to 5 mPa.s), or .1-40 s^{-1} (from 5 mPa.s).

Measurement in cereals

The procedure is the same as that described above, except for the prior ethanolic treatment which is not applied, and for the acetate buffer pH 4.5 which is replaced by an acidic solution (pH 1.5, HCl). The data obtained with this procedure are in good agreement with those obtained with the previous procedure (Figure 1).

Figure 1 Comparison between methods for the determination of potential applied viscosity (PAV) (g^{-1}.ml), in cereals



Real viscosity

The principle of this determination is to apply viscosity measurement on extracts obtained under conditions where enzymes may be active.

The procedure is the same as that of potential viscosity applied to samples of any origin, except that the prior ethanolic treatment is not performed.

Expression of viscosity data

The viscosity values (mPa.s) of extracts are divided by the viscosity of the extracting solution, giving the relative viscosities (h_r); then, h values are transformed into their Logarithm and divided by the concentration [C] of the original sample in the final aqueous extract. This transformation [Ln (h_r) / [C]] is called ((applied viscosity)) and expressed as g^{-1}.ml. This transformation has been performed in view to obtain additive data. The additivity of potential applied viscosities (PAV) has been checked on the 27 pelleted diets used for the bird assay (Figure 2). The real applied viscosity (RAV) cannot be considered additive because of possibilities of enzymatic cross-reactions between samples.

The coefficient of variations for repetitions of extractions and applied viscosity measurements is about 5%.

Potential Applied Viscosity (PAV) of Raw Materials

Potential applied viscosity measured in various raw materials showed great variability between types and also inside types of raw materials (Table 1). For instance, analyses of six samples of wheat produced PAV values varying between 1.64 and 5.16 g^{-1}.ml (dry matter basis). The lowest PAV values were observed for maize, sorghum, tapioca root and peas, and the highest for rye, barley and triticale (Table 1).

Figure 2 Additivity of potential applied viscosities (PAV) (g^{-1}.ml) checked on 27 pelleted diets

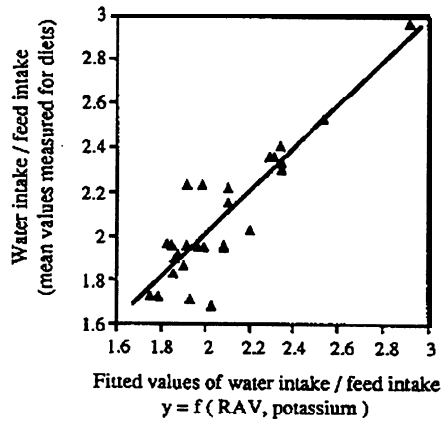


Table 1 Potential applied viscosities (g^{-1}.ml) measured in various raw materials (dry matter basis) used in poultry production.

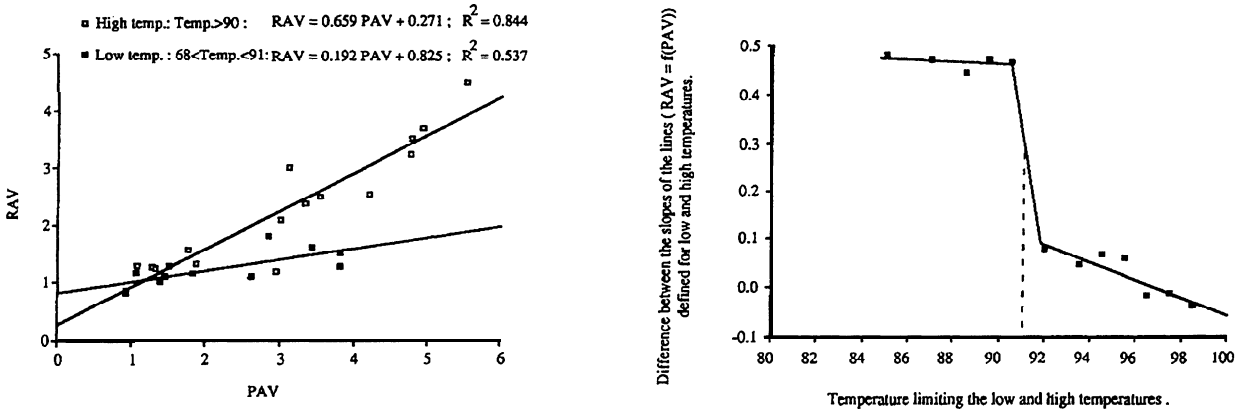
Maize	.60
Sorghum	.26
Wheat	1.64 - 5.16 (6)[1]
Barley	15.18 - 22.31 (4)
Triticale	2.77 - 7.27 (4)
Oat	13.22
Rye	27.21
Tapioca root	.36
Peas	.33 - 1.54 (19)
Soyabean meal 48	2.05
Rapeseed meal	1.33
Sunflower meal	1.44
Wheat shorts	4.52
Wheat bran	2.94 - 3.66 (2)

[1] Number within parentheses corresponds to the number of analyzed samples.

Effect of Pelleting Temperature on Real Applied Viscosity (RAV) Values

The outlet temperature of pelleting for the diets used in the bird assay varied between 68°C and 100°C. Relationship between PAV and RAV values differed according to outlet temperature: for low temperatures, RAV values remained rather low even if PAV values were high while, for high temperatures, RAV values were near to PAV values. Similarity between RAV and PAV values became the most evident for outlet temperatures above 91 °C (Figure 3). This suggests that nearly complete inactivation of enzymes occurred above 9 1 °C outlet temperature.

Figure 3 Calculations showing a minimum temperature (91°C outlet temperature of pelleting (2.5mm)) for the expression of real applied viscosity (RAV) (g^{-1}.ml). 27 pelleted diets are used in the calculations



Effect of Feed viscosity on Water Consumption and Excretion in Meat–Turkey Poults

Material and methods

Diets

Twenty seven diets were formulated to contain 23-26 % crude protein, 2900 kcal AME_n/kg, 1.5 % lysine, .95 % methionine + cystine, 1.4 % calcium and .6 % available phosphorus. All diets were supplemented with trace minerals, vitamins and .05 % robenidine. Twenty seven various raw materials were used, including maize (maximum: 42.5 %), wheat (maximum: 42.5 %), triticale (maximum: 47.4 %), barley (maximum: 17 %), oat (maximum: 20.1 %), tapioca root (maximum: 33.2 %), peas (maximum: 19.4 %), soyabean meal (maximum: 32.1 %), lucerne meal (maximum: 7.5 %), wheat bran (maximum: 8 %), soyabean isolate (maximum: 9.7 %), meat meal (maximum: 7 %), wheat straw (maximum: 6.3 %), canola oil (maximum: 4.9 %). Formulations were performed in order to vary the amounts of ashes, potassium, water-insoluble cell-walls (WICW), lipids and PAV. Diets were pelleted (2.5 mm) with outlet temperature varying between 68 and 100°C.

Pelleted diets were analyzed (Table 2) for ashes, for potassium and sodium using flame spectrophotometry, for WICW according to Carré and Brillouet (1989), for lipids according to the A European method (AFNOR 1985) and for PAV and RAV values according to the methods described above.

Bird assay

Male meat-turkey poults (Betiboul from Doux-Stanven-Betina) were raised from day 0 in individual metal cages placed in rooms controlled for temperature and humidity. From day 29, temperature was maintained at 2 1 °C, and light for 16 h per day. Cages were provided with individual controlled feeders and drinkers, and with individual plastic trays designed for total collection of excreta, put under the cages. Birds received a pelleted (2.5 mm) standard starter diet containing 29.6 % crude protein and 2970 kcal AME_n/kg from day 0 to day 28. Then, they received one of the 27 experimental diets, with 8 birds per diet. At day 34, excreta were collected for 24 h and 3 persons gave a visual score for structure defect (from 1 to 5) to each individual collection of excreta voided in the trays. The highest values of scores were given to the most liquid

Table 2 Range of compositions for the 27 experimental pelleted diets

N x 6.25 (%)	23.1	-	26.1
Lipids (L) (%)	4.5	-	9.1
Water–insoluble cell walls (WICW)(%)	11.2	-	17.1
Ashes (As) V	6.5	-	8.9
Sodium (%)	.11	-	.24
Potassium (%)	.59	-	1.06
Potential applied viscosity (g^{-1}.ml)	.9	-	5.5
Real applied viscosity (g^{-1}.ml)	.8	-	4.5
Dry matter (DM) (%)	87.8	-	90.7
Calculated AME_n [2] (kcal/kg)	2798	-	2988
Outlet temperature of pelleting (°C)	68	-	100

1For details, see Carré *et al.* 1994

[2] AME_n (kcal/kg) = 39.85 DM (%) + 47.02 L (%) - 53.07 As (%) -44.62 WICW (%) (Carré and Brillouet, 1989).

aspects, and the lowest to the most coherent aspects. A mean from the 3 persons was attributed to each bird. At days 36 and 37, the feed and water intakes were controlled and the excreta were collected twice daily for 48 h. Excreta were immediately weighed and stored at -20°C. Then, excreta were freeze-dried. The water losses of birds were measured as the weight losses resulting from the freeze-drying of whole excreta.

Effects of diets

The mean weight of birds was 1737 g at day 36 with no significant effect of diets. The daily feed intakes measured for the balance experiment (days 36 and 37) varied a little between diets ($P = .03$) from 147 to 184 g. Large variations were observed between diets ($P = .0001$) for the ratios [water intake: feed intake] (from 1.68 to 2.97) and [water excretion: feed intake] (from .86 to 1.74). Large variation between diets ($P = .0001$) was also observed for scores attributed to excreta (from 1.71 to 4.57).

Predictions of water excretion, water intake and excreta scores using diet composition

The mean values for the ratios [water intake: feed intake] and [water excretion: feed intake], and for excreta score attributed to each diet were related to feed analyses using correlations and calculations of multiple linear regressions (Figures 4-6).

Figure 4 Prediction of water intake / feed intake in 5-w. turkey poults using potassium content and real applied viscosity (RAV) of diets.

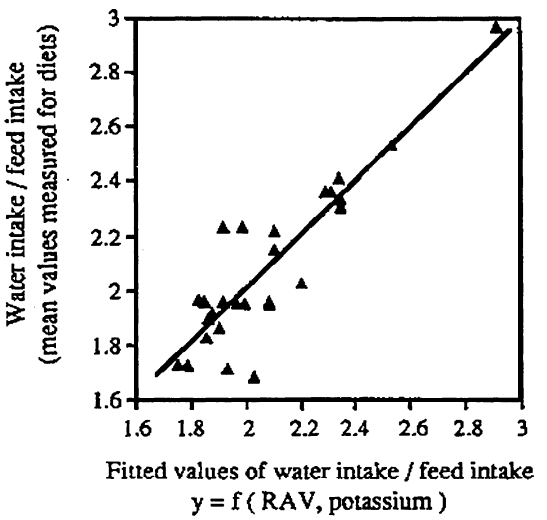


Figure 5 Prediction of water excretion / feed intake in 5-w. turkey poults using potassium content and real applied viscosity (RAV) of diets.

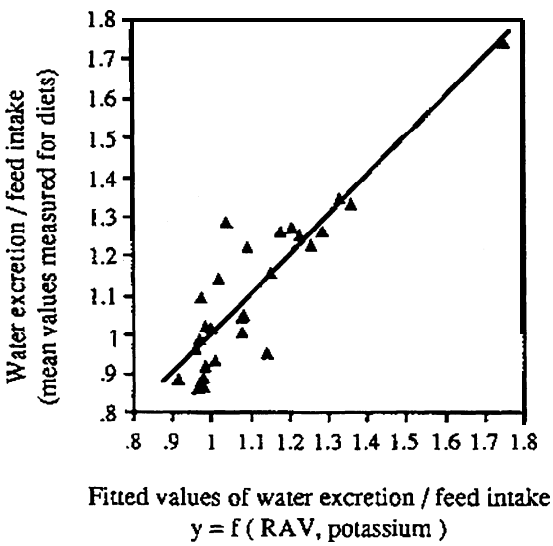


Figure 6 Prediction of visual score of excreta using real applied viscosity (RAV) of diets.

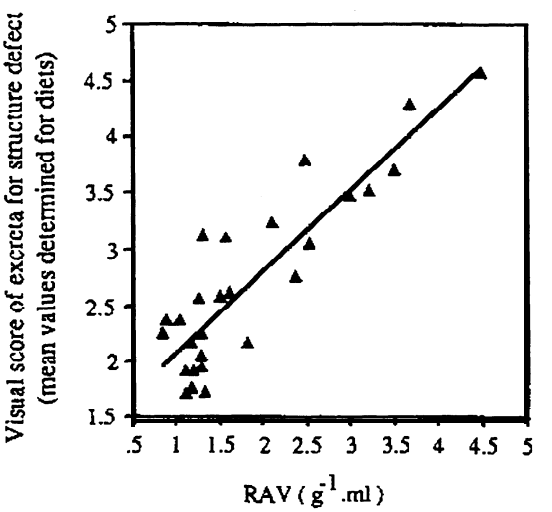


Table 3 – Correlation matrix

	Y1	Y2	Y3	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
Water intake/feed intake Y1	1.000	.941	.801	–.169	–.153	–.079	.273	–.065	.222	.685	.777	.443	.099	.416
Water excretion/feed intake Y2	.941	1.000	.779	–.216	–.239	–.096	.075	–.067	.036	.595	.713	.282	.044	.303
Excreta score Y3	.801	.779	1.000	–.249	–.430	–.346	.180	–.153	.186	.674	.886	.321	.184	.372
N*6,25 X1	–.169	–.216	–.249	1.000	.517	.189	–.005	–.404	.251	.001	–.190	.041	.271	–.114
Lipids X2	–.153	–.239	–.430	.517	1.000	.608	–.019	–.211	.193	–.184	–.280	.015	.135	–.214
WICW X3	–.079	–.096	–.346	.189	.608	1.000	–.387	.272	–.339	.057	–.078	.136	–.541	–.202
Ashes X4	.273	.075	.180	–.005	–.019	–.387	1.000	–.130	.813	.096	.148	.333	.199	.423
Sodium X5	–.065	–.067	–.153	–.404	–.211	.272	–.130	1.000	–.544	–.105	–.114	–.024	–.549	–.029
Potassium X6	.222	.036	.186	.251	.193	–.339	.813	–.544	1.000	.228	.242	.280	.411	.322
Potential applied viscosity X7	.685	.595	.674	.001	–.184	.057	.096	–.105	.228	1000	.850	.314	–.114	.196
Real applied viscosity X8	.777	.713	.886	–.190	–.280	–.078	.148	–.114	.242	.850	1.000	.436	.038	.417
Dry matter X9	.443	.282	.321	.041	.015	.136	.333	–.024	.280	.314	.436	1.000	.289	.835
Calculated AMEn X10	.099	.044	.184	.271	.135	–.541	.199	–.549	.411	–.114	.038	.289	1.000	.391
Outlet temperature of pelleting X11	.416	.303	.372	–.114	–.214	–.202	.423	–.029	.322	.196	.417	.835	.391	1.000

Table 4 – Equations (n = 27) expressing the water intake: feed intake (Y_1) and water excretion: feed intake (Y_2) ratios, and the visual score for structure defect of excretas (Y_3), as functions of real applied viscosity (X_1), potential applied viscosity (X_2), outlet temperature of pelleting (2.5 mm) (X_3), and potassium content (X_4), measured on diets given to 5w. meat–turkey poults.

$Y_1 = 0.236\ X_1 + 1.64$	Res. St. Dev. = 0.19. $R^2 = 0.588$
$Y_1 = 2.91 \times 10^{-6}\ X_2^2\ X_3^2 + 1.86$	Res. St. Dev. = 0.20. $R^2 = 0.540$
$Y_1 = (3.41\ X_4^2 - 6.36\ X_4 + 3.14)\ X_1 + 1.16\ X_4 + 0.63$	Res. St. Dev. = 0.15. $R^2 = 0.758$
$Y_1 = (9.50 \times 10^{-5}\ X_4^2 - 1.60 \times 10^{-4}\ X_4 + 6.89 \times 10^{-5})\ X_2^2\ X_3^2 + 1.83$	Res. St. Dev. = 0.16. $R^2 = 0.693$
$Y_2 = 0.146\ X_1 + 0.84$	Res. St. Dev. = 0.14. $R^2 = 0.489$
$Y_2 = 1.74 \times 10^{-6}\ X_2^2\ X_3^2 + 0.98$	Res. St. Dev. = 0.15. $R^2 = 0.411$
$Y_2 = (2.78\ X_4^2 - 5.16\ X_4 + 2.50)\ X_1 + 0.66\ X_4 + 0.23$	Res. St. Dev. = 0.10. $R^2 = 0.759$
$Y_2 = (6.53 \times 10^{-5}\ X_4^2 - 1.12 \times 10^{-4}\ X_4 + 4.92 \times 10^{-5})\ X_2^2\ X_3^2 + 0.96$	Res. St. Dev. = 0.12. $R^2 = 0.619$
$Y_3 = 0.724\ X_1 + 1.36$	Res. St. Dev. = 0.38. $R^2 = 0.775$
$Y_3 = 8.11 \times 10^{-6}\ X_2^2\ X_1^2 + 2.08$	Res. St. Dev. = 0.52. $R^2 = 0.580$

$0.83 \leq X_1 \leq 4.49$ (Ln (ηr).g^{-1}.ml); $0.91 \leq X_2 \leq 5.52$ (Ln (ηr).g^{-1}.ml);
$68 \leq X_3 \leq 100$°C; $0.59 \leq X_4 \leq 1.06$ %

The highest correlations were observed with the RAV variable (Table 3). The PAV variable gave lower correlations than RAV, which suggests that enzymes present in raw materials are effectively active in the digestive tract of birds.

Combining viscosity data with potassium content led to the most efficient regressions (Table 4). Potassium appeared in the regressions essentially as a modulator of slopes attributed to viscosity data: the lowest was the potassium content, the greatest was the slope for viscosity. This means that the sensitivity of birds to variations in viscosity was higher with low potassium than with high potassium contents. The RAV data may be predicted by the term [PAV x outlet temperature]^2, which explains the presence of the latter term in the regression lines (Table 4).

The results of the current experiment show that the diet formulation with PAV values and potassium together with the monitoring of outlet temperature of pelleting give the possibilities to control water intake and excretions in turkey poults.

Acknowledgements

Thanks are due to Mrs Joëlle Gomez (INRA-Nouzilly) for her excellent technical assistance in the measurements of viscosity and chemical parameters.

This work was supported by the grant no. 11 from Fonds SYPRAM and CRITT Valicentre.

References

AFNOR (1985) Aliments des animaux : méthodes d'analyse françaises et communautaires. Paris-La Defense.

BEDFORD, M.R. & CLASSEN, H.L. (1992) Reduction of intestinal viscosity through manipulation of dietary rye and pentosanase concentration is effected through changes in the carbohydrate composition of the intestinal aqueous phase and results in improved growth rate and food conversion efficiency of broiler chicks. *Journal of Nutrition,* **122: 560-569.**

CARRÉ, B. & BRILLOUET, J.M. (1989) Determination of water insoluble cell walls in feeds: interlaboratory study. *Journal of the Association of Official Analytical Chemists,* **72: 463-467.**

CARRÉ, B., GOMEZ, J., MELCION, J.P. & GIBOULOT, B. (1994) La viscosité des aliments destines à l'aviculture. Utilisation pour prédire la consommation et l'excrétion d'eau. *Productions Animales, 7: 369-*
379.

CHOCT, M., ANNISON, G. & TRIMBLE, R.P. (1992) Soluble wheat pentosans exhibit different anti-nutritive activities in intact and cecectomized broiler chickens. *Journal of Nutritrion,* **122: 2457-2465.**

GOHL, B., ALDEN, S., ELWINGER, K. & THOMKE, S. (1978) Influence of b-glucanase on feeding value of barley for poultry and moisture content of excreta. *British Poultry Science,* **19: 4 l-47.**

MORAN, E.T., LALL, S.P. & SUMMERS, J.D. (1969) The feeding value of rye for the growing chick: effect of enzyme supplements, antibiotics, autoclaving and geographical area of production. *Poultry Science, 48:*
939-949.

SMITH, M.O. & TEETER, R.G. (1989) Effects of sodium and potassium salts on gain, water consumption, and body temperature of 4 to 7 week-old heat stressed broilers. *Nutrition Report International,* 40: 161-169.

SMITH, J.D., BURKE, W.H. & SPEERS, G.M. (1973) The response of starting turkeys to moderate differences in dietary potassium concentration. *Poultry Science, 52:*
1344-1 348.