Effects of Feeding Xylose on the Growth of Broilers and Nutrient Digestibility as well as Absorption of Xylose in the Portal-drained Viscera

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ABSTRACT : Two experiments were conducted to examine the effects of dietary inclusion of xylose on growth performance, nutrient digestibility and xylose absorption in the portal-drained viscera of broiler chicks. In Exp. 1, ninety male 14 day-old broilers were used to study the effects of different inclusion levels (0, 5, 10, 20 and 40%) of D-xylose in the semi-purified diets on the growth and nutrient digestibility of broilers. In Exp. 2, One hundred and eight male broilers, fed by precision feeding at 22 day-old, were used to investigate the absorption and transportation of dietary xylose in the portal-drained viscera of broiler. The results of Exp. 1 indicated that the growth of broilers was gradually decreased as the xylose level increased ($p<0.01$). With the xylose supplementation increased, the moisture in broiler excreta was gradually elevated ($p<0.01$), AME and the digestibilities of crude protein and ether extract were significantly reduced and the digestibilities of xylose and arabinose were also decreased ($p<0.01$). The results of Exp. 2 showed that the concentrations of ribose, xylose and galactose in serum were significantly influenced by different dietary levels of xylose ($p<0.01$), but there's no apparent difference among rhamnose, glucose and arabinose ($p>0.05$). The xylose concentration in serum was highest in Vena Cava, middle in Portal Vein and lowest in Ulnar Vein within 6 h after precision feeding. And then the xylose concentration in Portal Vein and Ulnar Vein were higher than that of Vena Cava. The concentration of ribose, xylose and galactose in serum were also significantly changed with time prolongation ($p<0.01$). The concentration of xylose in serum was highest in the 40% xylose treatment, middle in the 20% xylose group and lowest in the control group. The glycogen contents in liver and muscle were linearly decreased as the level of xylose increased ($p<0.01$). The higher the dietary level of xylose was, the lower digestibility of dietary xylose was ($p<0.10$). 40% xylose markedly decreased the digestibility of dietary glucose ($p<0.01$). In conclusion, high levels of xylose in the diets inhibited the growth and nutrient digestibility of broiler. The outputs of xylose from the hydrolyzation of wheat-based diet by xylanase should have no adverse effects on broiler performance. ***(Asian-Aust. J. Anim. Sci. 2004. Vol 17, No. 8 : 1123-1130)***

Key Words : Xylose, Broiler, Growth, Nutrient Digestibility, Absorption

INTRODUCTION

Xylose is a pentose sugar and its molecular formula is $C_5H_{10}O_5$. In terms of sweetness, it has a value of 40 when compared to sucrose set at 100. Monogastric animals are unable to utilize this 5 carbon sugar (Miller and Lewis, 1932), which suggests that it may be used as a dietary sweetening agent by individuals who desire to reduce body weight. The tendency of this sugar to cause diarrhea in laboratory animals suggests its possible use in laxative preparations. Xylose has special psychological functions that can promote proliferation of *Bifidobacterium adolescentis* in the human and animal's intestine tract and improve the absorption of dietary calcium. Dietary xylitol probably prevents the reduction in nitrogen retention with growth retardation due to immunological stimulation (Takahashi et al., 2002).

The carbohydrate fraction of many feed ingredients, including soybean meal, rapeseed meal, barley, rye, oat, and wheat bran, consists mainly of non-starch polysaccharides (NSP) (Peng et al., 2003). Chesson (1987) concluded that the digestibility of feed ingredients containing high levels of NSP could be improved by treatment with enzymes that can hydrolyze the NSP to monosaccharides. However, hydrolysis of NSP will release not only glucose, but also sugars such as xylose and arabinose, which are normally not encountered in the small intestine. The outputs of pentose sugars from *in vitro* digestion of wheat by xylanase were 4.5-6.1 g/kg (Zyla et al., 1999). The concentrations of xylose and arabinose in enzyme-extracted solution, measured by HPLC, were 3.0 g/kg and 3.0 g/kg, respectively (Tervilä-Wilo et al., 1996). Unpublished data in our laboratory showed that output of pentose sugars were 5.96 g/kg when wheat-based diet was digested *in vitro* by xylanase. The effects of these pentose sugars from xylanase-extracted wheat diet on the broiler performance and the absorption of xylose has not as yet been adequately studied.

The objectives of this investigation were to determine whether different dietary levels of xylose impair growth and physiological well-being of chicks and to study the effects of dietary xylose concentration on its relative absorption rate.

MATERIALS AND METHODS

Birds and experimental design

One hundred and ninety eight day-old Avian male broiler chickens were obtained from a commercial hatchery

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Table 1. Composition and nutrient levels of semi-purified diets in Experiment 1 and Experiment 2

Ingredients (%)	Dietary treatments (xylose levels)				
	0	5%	10%	20%	40%
Glucose	60	55	50	40	20
Xylose[1]	0	5	10	20	40
Soybean meal	25.21	25.21	25.21	25.21	25.21
Isolated soybean protein	6	6	6	6	6
Fibre	2	2	2	2	2
Vegetable oil	2	2	2	2	2
Dicalcium phosphate	2.41	2.41	2.41	2.41	2.41
Limestone	1.1	1.1	1.1	1.1	1.1
Sodium chloride	0.35	0.35	0.35	0.35	0.35
Methionine	0.3	0.3	0.3	0.3	0.3
Lysine	0.31	0.31	0.31	0.31	0.31
Mineral premix[2]	0.2	0.2	0.2	0.2	0.2
Vitamin premix[3]	0.02	0.02	0.02	0.02	0.02
Choline chlorine	0.1	0.1	0.1	0.1	0.1
Total	100.0	100.0	100.0	100.0	100.0
Nutritive level (analyzed value)					
ME (MJ/kg)	13.9	14.1	13.9	13.5	13.3
Crude protein (%)	17.0	17.1	16.9	17.1	17.0
Ca (%)	1.0	1.1	1.0	1.0	1.1
Available P (%)	0.45	0.45	0.45	0.45	0.45
Lysine (%)	1.09	1.00	1.03	1.00	1.00
Methionine (%)	0.51	0.48	0.49	0.50	0.49
Xylose (%)	0	4.1	8.2	16.4	32.7
Arabinose (%)	0	0.6	1.1	2.2	4.4
Glucose (%)	60.0	55.0	50.1	40.2	20.3

[1] Compositions of commercial xylose: xylose 81.7%, arabinose 11.0%, ribose 4.7%, rhamnose 2.5%, glucose 0.8%, mannose 0.6%, galactose 0.03%.

[2] Trace elements premix (supplied per kg feed): Cu 8 mg, Zn 75 mg, Fe 80 mg, Mn 100 mg, Se 0.15 mg, I 0.35 mg.

[3] Vitamin premix (supplied per kg feed): retinyl acetate 12,500 IU, cholecalciferol 2,500 IU, DL-α-tocopheryl acetate 18.75 mg, meneadione sodium bisulphite 2.65 mg, thiamin mononitrate 2 mg, riboflavin 6 mg, cyanocobalamin 0.025 mg, biotin 0.0325 mg, folic Acid 1.25 mg, calcium pantothenate 12 mg, nicotinic acid 50 mg.

and reared in an environment-controlled broiler-house. All broilers were fed commercial diet till 12 day-old. All birds were raised in three-layer cages with wire bottom floors. The birds were inoculated vaccines according to the normal immunization procedures of broilers. Experimental procedures were evaluated and approved by the Institutional Animal Care and Use Committee at China Agricultural University.

Exp. 1 was designed with 90 male broilers of 14 day-old to investigate the effect of dietary inclusion rates of 0, 5, 10, 20 and 40% of D-xylose on chick performance and feed utilization. There were five dietary treatments; each treatment had six pens (replicates) of three birds. Metabolism balance trial was conducted using a classical total excretion collection method (including both faces and urine) during the period of 16 to 21 d age of broilers (Mollah et al., 1983).

The main objective of Exp. 2 with 108 male broilers at 22 day-old was to get more information on the quantitative aspects of absorption and transportation of D-xylose at dietary inclusion levels of 0, 20 and 40%. In a completely randomized 3×6 factorial (xylose×time) design, three levels of xylose were 0, 20 and 40% and six time points were 0, 2, 4, 6, 8 and 12 h, respectively. Each treatment had six pens (replicates) of one bird. These birds were precisely force-fed with 30 g of semi-purified diet per chick at 22 day-old through a stainless steel tube.

Experimental diet

The composition of the experimental diets used in Exp.1 and Exp. 2 were given in Table 1. The 60% D-glucose diet was used as a control. In the other diets, a proportional part of D-xylose was substituted at the expense of D-glucose (A.R.). Birds were given free access to mash feed and water.

Sample and chemical analysis

At the end of Exp. 1, chicks were weighed per pen, and feed consumption of each cage was recorded. Excreta were collected quantitatively from glass trays into containers and stored at 4°C. The excreta samples from each pen were pooled, dried at 65°C in a forced-draft oven and ground through 1 mm sieve before analysis. Proximate analysis was performed according to standard procedures (AOAC, 1990). Gross energy of diet and excreta samples was assayed using an adiabatic oxygen bomb calorimeter. At the end of the trial, liver sample and leg muscles sample were taken and

Table 2. Effects of different levels of xylose on the growth performance of broilers

Items	Xylose levels					p<	SEM
	0	5%	10%	20%	40%		
Feed intake (g/d)	78.6 [a]	80.9 [a]	73.9 [ab]	67.3 [b]	58.4 [c]	0.000	1.88
ADG (g/d)	39.0 [a]	36.0 [ab]	33.8 [b]	21.9 [c]	3.9 [d]	0.000	2.47
Feed/gain	2.03 [a]	2.15 [a]	2.18 [a]	3.18 [a]	16.67 [b]	0.000	1.13

[a-d] Means within a row lacking a common superscript letter differ significantly (p<0.05).

Table 3. Effects of different dietary levels of xylose on the excreta moisture, AME and the digestibility of protein and fat

Items	xylose levels					p<	SEM
	0	5%	10%	20%	40%		
Moisture in excreta (%)	65.1[a]	76.1[b]	78.8[bc]	82.4[bc]	84.3[c]	0.000	1.63
AME (MJ/kg)	13.9[ab]	14.1[b]	13.9[ab]	13.5[a]	13.7[ab]	0.049	0.06
Digestibility of protein (%)	88.1[c]	87.8[c]	85.8[bc]	83.2[b]	79.2[a]	0.003	0.91
Digestibility of fat (%)	85.1[c]	82.5[bc]	80.1[b]	73.3[a]	73.7[a]	0.000	1.20

[a, b, c] Means within a row lacking a common superscript letter differ significantly (p<0.05).

Table 4. Effects of different levels of xylose on the glycogen content in liver and muscle

Xylose levels	Glycogen in liver (mg/100 g tissue)	Glycogen in muscle (mg/100 g tissue)
0	2,246.7[a]	548.7[a]
20%	1,102.2[b]	348.7[b]
40%	268.9[c]	136.5[c]
p<	0.000	0.000
SEM	71.0	43.7

[a, b, c] Means within a column lacking a common superscript letter differ significantly (p<0.05).

deep-frozen with liquid nitrogen as soon as possible. Liver and muscle glycogen analyses were made according to Carroll et al. (1956).

Blood samples in Exp. 2 from Ulnar Vein, Vena Cava, and Portal Vein were collected on the 0, 2, 4, 6, 8 and 12 h after precision feeding, respectively. At certain time, 3 ml blood sample were firstly taken from Ulnar Vein with a 5 ml syringe. And then the same bird was anaesthetized through inhaled aether and its abdomen was opened and Portal Vein was separated. About 1 ml blood sample were slowly taken from Portal Vein with a 1 ml syringe. At last, 2 ml blood sample were taken from Vena Cava. After that, this bird was abandoned and other force-fed birds were used to take blood samples at next time. All blood samples were centrifuged at 3,000×g for 20 minutes. The collected serum was subjected to the serum monosaccharides determination. One ml serum was diluted with 10 ml distilled water (1:10), deproteinized with potassium ferrocyanate and zinc acetate. Sugar concentrations in feed and excreta sample as well as serum sample were determined as silylderivatives of monosaccharides by gas liquid chromatography (Harris et al., 1988).

Statistical analysis

The data in Exp. 1 were subjected to analysis of variance using the one-way ANOVA procedure of Statistical Package for the Social Science (SPSS 10.0) and reported by means of LSD's multiple range test. Data in Exp. 2 were statistically analyzed by the GLM procedure of SPSS and LSD's multiple range test was used to report the differences among the treatment means. The Correlation and Regression procedure of SPSS were also used in both trials. All statements of significance are based on a probability of p<0.05 unless indicated otherwise.

RESULTS

Effects of graded levels of D-xylose on the chick growth performance and nutrient digestibility

The mean values for feed intake and gain weight in birds fed the D-xylose diets are given in Table 2. Negative dose-dependent effects of D-xylose on weight gain, daily intake and feed utilization were observed. The linear correlation between Average Daily Gain (Y) and xylose level (X) existed (p<0.01). A quadric response of feed conversion ratio (Y) to dietary xylose level (X) was observed (p<0.01). The regression between feed intake (Y) and dietary xylose level (X) was linearly significant (p<0.01) (Table 6). No appreciable differences in mortality among the treatments were observed. Gross pathological examination of the liver did not shown abnormalities in birds fed on the different diets.

The moisture content in the droppings and nutrient digestibility are presented in Table 3. The dry matter of droppings decreased when dietary D-xylose increased (p<0.01). The relationship between the moisture in excreta (Y) and dietary xylose level (X) was quadric (p<0.01) (Table 6). When the xylose level was 29.5%, the moisture in excreta attained the peak value 86.4%.

Dietary AME tended to decrease as dietary D-xylose increased (p<0.05). A significant linear decrement in protein digestibility (Y) occurred as the dietary level of D-xylose (X) increased (p<0.01). A quadric response of fat digestibility (Y) to dietary xylose level (X) was observed (p<0.01) (Table 6). The digestibility of fat attained the minimum value (72.2%) at a dietary inclusion of 30.6% D-

Table 5. Effects of xylose on the digestibility of xylose, arabinose and glucose in semi-purified diets

Items	Xylose levels					p<	SEM
	0	5%	10%	20%	40%		
Xylose (%)	-	97.8[a]	98.3[a]	91.9[b]	87.3[c]	0.000	1.09
Arabinose (%)	-	88.0[a]	89.8[a]	66.4[b]	57.2[c]	0.000	3.58
Glucose (%)	99.89[a]	100.0[a]	100.0[a]	99.9[a]	99.2[b]	0.000	0.057

[a, b, c] Means within a row lacking a common superscript letter differ significantly ($p<0.05$).

Table 6. The regression analyses between different items (Y) and the xylose level (X)

Model	Dependent (Y)	Variance (X)	Regression equation	R^2	Probability	n
Linear	Average daily gain	Xylose level	$Y=40.54-0.91X$	$R^2=0.929$	$p<0.01$	n=30
Quadric	Feed/gain	Xylose level	$Y=2.54-0.23X+0.01X^2$	$R^2=0.918$	$p<0.01$	n=30
Linear	Feed intake	Xylose level	$Y=80.19-0.56X$	$R^2=0.612$	$p<0.01$	n=30
Quadric	Moisture in droppings	Xylose level	$Y=67.03+1.31X-0.02X^2$	$R^2=0.665$	$p<0.01$	n=30
Linear	Protein digestibility	Xylose level	$Y=88.32-0.23X$	$R^2=0.718$	$p<0.01$	n=30
Quadric	Fat digestibility	Xylose level	$Y=85.34-0.99X+0.02X^2$	$R^2=0.652$	$p<0.01$	n=30
Linear	Xylose digestibility	Xylose level	$Y=99.96-0.33X$	$R^2=0.698$	$p<0.01$	n=30
Linear	Arabinose digestibility	Xylose level	$Y=93.0-0.96X$	$R^2=0.597$	$p<0.01$	n=30
Linear	Glucose digestibility	Xylose level	$Y=100.06-0.02X$	$R^2=0.677$	$p<0.01$	n=30
Linear	Liver glycogen	Xylose level	$Y=3012.82-860.7X$	$R^2=0.823$	$p<0.000$	n=18
Linear	Muscle glycogen	Xylose level	$Y=756.78-206.08X$	$R^2=0.883$	$p<0.000$	n=18

Table 7. Variety of serum monosaccharide concentration[1] in different position with time prolongation owing to precision feeding different levels of xylose

Main effects		Monosaccharide concentration in serum (mg/ml)				
		Rhamnose	Ribose	Xylose	Galactose	Glucose
Position	Portal vein	1.29	1.20	5.08	0.54	2.17[a]
	Vena cava	1.43	1.50	5.01	0.57	3.23[b]
	Ulnar vein	1.29	1.66	4.32	0.57	1.88[a]
Time	0	1.43	1.91[b]	0.34[a]	0.56[a]	1.86
	2 h	1.32	1.99[b]	6.63[b]	0.41[a]	2.45
	4 h	1.13	1.74[ab]	6.83[b]	0.28[a]	2.50
	6 h	1.36	1.54[ab]	6.36[b]	0.51[a]	2.13
	8 h	1.32	1.55[ab]	6.16[b]	0.56[a]	2.40
	12 h	1.47	1.19[a]	2.50[ab]	1.02[b]	3.22
Xylose level	0	1.30	1.36[ab]	0.48[a]	0.60[ab]	2.47
	20%	1.40	1.97[b]	5.86[b]	0.68[b]	2.74
	40%	1.32	1.04[a]	8.07[b]	0.40[a]	2.07
Source of variation				Probabilities		
Position		NS	NS	NS	NS	0.006
Time		NS	0.020	0.005	0.002	NS
Xylose level		NS	0.008	0.000	0.050	NS
Pooled SEM		0.046	0.186	0.635	0.055	0.186

[1] No arabinose value indicated in the table was that the arabinose concentration in serum couldn't be found (its concentration is lower than 0.01 mg/ml).
[a, b] Means within a column lacking a common superscript letter differ significantly ($p<0.05$).
NS: no significance ($p>0.05$).

xylose. The correlation coefficient between dietary AME and fat digestibility was 0.572 ($p<0.01$). No significant correlation between dietary AME and protein digestibility was observed ($p>0.05$).

Table 4 and Table 6 showed that the glycogen contents in liver and muscle were linearly decreased as the dietary level of xylose increased ($p<0.01$).

Effects of xylose on the digestion and absorption of monosaccharides

Table 5 summarized monosaccharides digestibility data collected. The digestibilities of xylose and arabinose were decreased linearly as the dietary level of D-xylose increased ($p<0.01$) (Table 6). The glucose digestibility was significantly affected by dietary inclusion of 40% xylose though the digestibility of glucose was approximately 100% ($p<0.01$). An obvious linear relation between the glucose digestibility (Y) and the xylose levels (X) existed ($p<0.01$) (Table 6).

Table 7 indicated the concentrations of ribose, xylose and galactose in serum were significantly influenced by different dietary levels of xylose ($p<0.01$), but that of

rhamnose, glucose and arabinose have no differences ($p>0.05$). The concentration of ribose, xylose and galactose in serum markedly changed with time prolongation ($p<0.01$). The xylose concentration in serum was highest at a dietary inclusion of 40% xylose, middle at 20% and lowest in the control. The xylose concentration in serum between the 20 and 40% treatment were consistent within 4 h after precision feeding. And then, the xylose concentration in the 40% xylose group was higher than that of 20% xylose group. This suggests that the maximum absorption of xylose for broils was limited to some extent.

Table 7 also showed the glucose concentration in Ulnar Vein was significantly inferior to that in Vena Cava and Portal Vein ($p<0.01$), but the other monosaccharides (such as rhamnose, ribose, arabinose and galactose) had no difference ($p>0.05$). The xylose concentrations in different sites such as Portal Vein, Vena Cava and Ulnar Vein changed with time prolongation ($p<0.01$). The xylose concentration in serum was highest in Vena Cava, middle in Portal Vein and lowest in Ulnar Vein within 6 h after precision feeding. And then, the xylose concentration in Portal Vein and Ulnar Vein were higher than that of Vena Cava.

DISCUSSION

The digestive enzymes of monogastric animals hydrolyze most of the alimentary components with the exception of the NSPs (cellulose, hemicellulose, pectins, oligosaccharides, etc). The absence of NSP-degrading enzymes in the host and the low density of microorganisms in the small intestine of chicks mean that the NSP will largely pass to the hindgut, and be degraded there to some extent by the microbes. In contrast to pigs, microbial degradation of NSP in the caeca and colon of poultry appears to be low (Nahm and Carlson, 1985). Improvement of the digestibility and utilization of NSP could be attained by including enzymes in the diets (Chesson, 1987; Peng et al., 2003). However, a complete hydrolysis of the NSPs will release not only glucose, but also other sugars such as D-xylose and L-arabinose. It is well recognized that both pentose sugars are absorbed from the intestinal tract in birds.

Effects of xylose on AME and nutrient digestibility

In the present trails, the moisture in droppings and the severity of diarrhea were gradually elevated as dietary xylose level increased. This reflected the osmotic properties of unabsorbed pentose sugars. The presence of unabsorbed xylose in the intestinal tract of birds might stimulate microbial activity and consequently resulted in an inflow of water into the intestinal lumen (Zyla et al., 1999).

The lower available energy in semi-purified diet with xylose in the present trial was in agreement with the observation in some previous studies with chicks (Anderson et al., 1958; Wagh and Waibel, 1966; Schutte, 1990). The AME value for D-xylose and L-arabinose were much lower than that of D-glucose and were dose-dependent (Anderson et al., 1958). Using the ME value for glucose 15.1 MJ/kg as a reference, the determined values of metabolizable energy for arabinose and xylose were 12.8 and 10.5 kcal/g of respective carbohydrate (Anderson et al., 1958). Wagh and Waibel (1966) reported consistent data, showing the average metabolizable energy values for dietary arabinose and xylose at 20% were 12.8 and 10.6 MJ/kg of pentose, respectively. Longstaff et al. (1988) reported the AME of glucose, xylose and arabinose diets were 14.0, 12.0 and 11.8 MJ/kg, respectively. Schutte (1990) reported the AME values for D-xylose at 5 and 10% dietary inclusion were 11.1 and 8.4 MJ/kg, respectively.

The decrease in energy value of pentose sugars by increasing the dietary levels might be due to decreased absorption capacity, or/and an increased urinary excretion. A decrease in the utilization of the other energy-bearing components in the diet might be another cause, resulting in a lower derived AME value for pentose sugars. It was recognized that in man, rats, and pigs, part of the ingested D-xylose and L-arabinose appeared in the urine (Wise et al., 1954; Arnal-Peyrot and Adrian, 1974). The urinary excretion increased linearly as the dietary inclusion level increased (Arnal-Peyrot and Adrian, 1974). In roosters fed the 2.5% D-xylose diet, 7.2% of the consumed D-xylose appeared in the urine. This excretion level increased to 20.2% when roosters were fed a diet containing D-xylose 10.0%.

Unpublished data in our lab showed that the chick (3 to 4 weeks of age) digested wheat pentosans to an extent of 25%, in contrast with sugar and starch that were almost fully utilized. Schutte et al. (1993) reported D-xylose and L-arabinose only provided limited energy (25-35% of D-glucose).

The digestibilities of crude protein and fat in semi-purified diet were markedly decreased as dietary xylose level increased (Table 3). This might be explained by that nutrients were dyspeptic and malabsorptive due mostly to diarrhea. The increase in plasma uric acid resulting from 20 and 40% xylose might be due to relative energy deficiency as related to the protein intake and consequently greater nitrogen metabolism (Wagh and Waibel, 1966). They suggested an increased N catabolism when birds were fed on D-xylose diets. There were some indications that, even at lower dietary inclusion rates, pentose sugars influence N utilization adversely (Schutte et al., 1993). A decreased fat digestibility for xylose addition might be the result of metabolic effects on cholesterol synthesis. As consistent increases in the plasma cholesterol level were observed in relation to the higher dietary levels of xylose, pentose

sugars might participate either in influencing cholesterol synthesis or inhibiting its excretion. Plasma cholesterol was significantly higher among birds receiving a 40% xylose diet (Wagh and Waibel, 1966). The fat content in liver and droppings was decreased as dietary pentoses increased (Wagh and Waibel, 1967b). Loss in liver weight suggested the further possibility of alimentary excretion of energy-bearing components, namely, cholesterol and bile acids (Anderson et al., 1958).

Effects of xylose on chick performance

The pentose sugars might affect negatively on the utilization of dietary ME and then depressed performance. Inclusion of 40% L-arabinose and D-xylose in chicks' diet resulted in a severe depression of growth and feed efficiency (Wagh and Waibel, 1966). Twenty percent xylose also depressed growth significantly. A considerable reduction in the ADG of the birds fed high levels of pentoses reflected the severe growth retardation and the low feed consumption. Even at the very low dietary inclusion level of 2.5%, both D-xylose and L-arabinose affected performance adversely (Schutte, 1990).

In the present trial, weight gain and food utilization of birds fed on diets containing xylose were inferior to those fed on the reference diet. The depression of broiler growth was mostly attributed to the lower AME value of xylose compared to glucose and the decrease in feed intake and nutrient digestibility. Depressed feed intake in Exp.1 as a result of feeding D-xylose to chicks was also observed in a previous study (Schutte, 1990). The birds' dislike for D-xylose had been demonstrated by Kare and Medway (1959), who showed an almost total rejection of water solutions containing this pentose sugar. Other sugars such as lactose, galactose, raffinose and arabinose had only minor effects on water consumption.

Feed conversion ratio attained the peak value when xylose inclusion rate was 7.9%. The extent of the reduction in food utilization was very small when dietary xylose level was 5% in the present trial. The outputs of pentose sugars were 4.5-6.1 g/kg when wheat-based diet was hydrolyzed by xylanase. So it can be concluded that those pentose sugars should have no adverse effects on chick performance.

Effects of xylose on monosaccharide digestibility and glycogen content in liver and muscle

The digestibility of glucose and xylose were almost 100% and 87-97% respectively, however that of arabinose was 57-88%. Pentose sugars digestibility tended to decrease as dietary level of xylose increased. It was in line with the finding of Longstaff et al. (1988) that the digestibilities of glucose, xylose and arabinose were 100, 93.6 and 62.8%, respectively, and the ileal digestibility of D-glucose and D-xylose was nearly 100% (Schutte et al., 1991). Ileal digestibility of L-arabinose decreased linearly as dietary dose increased. The data demonstrated that L-arabinose was not absorbed completely from the small intestine, but D-xylose was absorbed from the small intestine of birds as well as D-Glucose. Wagh and Waibel (1967a) reported that absorbed L-arabinose and D-xylose were 58.6 and 85.5% of D-glucose, respectively. Bogner (1961) found absorbed L-arabinose and D-xylose were 45.6 and 79.7% of D-glucose, respectively.

Inclusion of 40% D-xylose or L-arabinose in chicks' diet resulted in a severe glycogen depletion in liver and muscle (Wagh and Waibel, 1966), which was highly in agreement with our present results, that liver and muscle glycogen was proportionally depleted with increase in dietary pentose level. At dietary inclusion of 10 to 40% xylose, liver weight and liver glycogen decreased, indicating a depletion of liver glycogen due to energy deprivation. The severe glycogen depletion in liver and muscle of chicks at 20 and 40% of dietary xylose might be attributed to an interruption of glycogen synthesis. Were the pentoses in question freely metabolized and converted to glucose by the chicks, glycogen should not have been depleted from the liver. This hypothesis can be further substantiated from the liver and muscle glycogen values among the birds fed cellulose (Wagh and Waibel, 1966). Since cellulose was not utilized by chicks and the available energy to the bird, therefore, was lacking, the lower values of liver and muscle glycogen could be attributed to glycogenolysis.

Absorption and metabolism of xylose

D-xylose is absorbed from the upper small intestinal tract, similar to the sodium-dependent active transport of glucose and amino acids (Goodwin et al., 1984). In the chicken, xylose was actively absorbed and shares a common mobile-transport carrier with glucose and amino acids, similar to the condition of found in mammals (Alvarado, 1966; Alvarado and Monreal, 1967). If the monosaccharide is a nonmetabolizable sugar such as D-xylose, the transport of both D-xylose and sodium can be greatly depressed if the cell without energy in the form of glucose. D-xylose and L-arabinose, in spite of their identical molecular size, have a different mode of transport in the small intestine of birds. It is generally accepted (Herman, 1974) that L-arabinose is passively absorbed in the small intestine of animals. However, the transport of D-xylose from the animal intestine is by the same mechanism as D-glucose (Salomon et al., 1961; Alvarado, 1966; Bihler et al., 1969). Lack of Na^+-dependent active transport of nutrients such as glucose and amino acids would result in many of the signs such as diarrhea, wasting of musculature, lack of growth and stunting (Perry et al., 1991).

In the present trial, the absorption rate of xylose within

6 h after precision feeding was too fast to be excreted by kidney in time. Consequently partial xylose was accumulated in the circulation system and the xylose concentration in Vena Cava was higher than that in Portal Vein. Increases in the total reducing sugars in blood with increasing dietary xylose suggested that the pentoses entering in the blood stream were accumulated prior to excretion or utilization. With time prolongation, the absorption rate became slower and the xylose storage in blood was gradually depleted, so the xylose concentration in Portal Vein was higher than that in Vena Cava. This can be explained that the capacity limitation of xylose excretion by kidney.

The appearance of higher concentrations of xylose than arabinose in plasma and no appreciable difference of blood glucose in chicks observed in the present study agrees with the data of Wagh and Waibel (1967a), suggesting a faster absorption of the former. The absorption rates of L-arabinose and D-xylose were consistently lower as compared to that of D-glucose. The relative absorption of L-arabinose and D-xylose were 58.6 and 85.5%, respectively, of D-glucose.

Both dosage and type of sugar influenced absorption. Increase in the dosage correspondingly increased absorption velocity. It appeared that L-arabinose and D-xylose, in spite of their identical molecular size, had different rates of movement and absorption. The priority of absorption rates as D-glucose>D-xylose>L-arabinose only occurred at the lower concentration of sugars administration. At high concentration, the priority was as D-xylose>D-glucose>L-arabinose. Outputs of pentose sugars from the hydrolyzation of wheat-based diet by xylanase were very low and the bulk of dietary glucose inhibited the xylose absorption. So the increase of absorbed pentose from wheat-based diet for xylanase addition was very limited.

Only a few reports were available concerning the metabolism of pentose sugars in birds. Radioisotope studies of Wagh and Waibel (1967a) showed that L-arabinose was better metabolized than D-xylose by chicks, but neither pentose sugar was metabolized to CO_2 as rapidly as D-glucose. The estimated poor-utilization of the ME of D-xylose and L-arabinose probably relates to the metabolic pathways of these sugars. In a previous study (Schutte et al., 1991) with adult roosters it was found that about 15% of the ingested D-xylose or L-arabinose was excreted in the urine. The remaining part may have either been metabolized to carbon dioxide or/and fermented in the intestinal tract. According to Segal and Foley (1959), metabolism of these two pentose sugars to carbon dioxide is only of significance for D-xylose. When human is given an intravenously infused dose of ^{14}C-labelled D-xylose, 16% was recovered as carbon dioxide. Xylose might be fermented mainly in the intestinal tract of chicks when fed orally. From these results it was concluded that at least part of the ingested pentose was degraded microbially. Microbial degradation of D-xylose in chicks occurs mainly in the crop and small intestine, because ileal digestibility of xylose was found to be nearly 100% in adult roosters (Schutte et al., 1991).

CONCLUSION

In conclusion, high level of xylose in the diet seriously inhibited the growth of broilers and the digestibilities of dietary protein and fat. High level of dietary xylose significantly decreased the digestibility of arabinose and glucose as well as the glycogen content in liver and muscle. Negligible amounts of xylose and arabinose from the hydrolyzation of wheat-based diets by xylanase should have no adverse effects on broiler growth performance.

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