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Effects of different sources and levels of dietary gossypol on gossypol residues in plasma and milk of lactating cows

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ABSTRACT

Free gossypol residues in tissues or milk from feeding whole cottonseed and cottonseed meal were measured for their effect on health of dairy cows and humans. Forty lactating cows were randomly assigned to 5 treatments in a 60-d experiment to investigate the effects of sources and dietary level of gossypol on plasma and milk gossypol concentrations in lactating cows. Five experimental diets had identical net energy for lactation and crude protein content on a dry matter (DM) basis. Soybean meal was the main protein ingredient used in the control diet. Cottonseed meal (CSM) or whole cottonseed (WCS) substituted for part of the soybean meal in the other 4 diets. Gossypol levels in the 5 diets were 0 (control), 91.15 mg/kg of DM in CSM1, 117.31 mg/kg of DM in CSM2, 385.43 mg/kg of DM in WCS1, and 611.13 mg/kg in WCS2. Yields of 3.5% fat-corrected milk were significantly higher for cows in the WCS2 group; cows in the CSM1 and WCS1 groups showed no differences but both were numerically higher than the control and CSM2 groups. Milk protein concentration was lower for cows consuming WCS1 compared with the control group. Lactose concentration was lower for cows in the CSM2 group compared with the WCS2 group, but no differences were observed among other diets. Aspartate aminotransferase in serum was significantly higher for the WCS2 group compared with the control and WCS1 groups, but no difference was observed with the CSM1 and CSM2 groups. Concentrations of gossypol in plasma and milk of cows in the WCS1 and WCS2 groups were both higher than those of the other groups. No adverse effects were observed on cows fed diets containing 12.0% CSM, and no gossypol was found in plasma and milk. When WCS comprised 15% of the diet DM, yields of 3.5% fat-corrected milk were increased in cows and gossypol was detected in plasma and milk but not at harmful levels.

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INTRODUCTION

Whole cottonseed (**WCS**) and cottonseed meal (**CSM**) are extensively used as energy and protein sources in dairy cattle diets. However, both contain gossypol, a polyphenolic binaphthyl dialdehyde that can produce toxic effects in animals. Gossypol exists in free and bound forms. Free gossypol (**FG**) is toxic to animals, whereas the bound form is considered nontoxic because it cannot be absorbed in the digestive tract. Some researchers have found that bound gossypol may be released as FG during the digestion process, which can be absorbed by the digestive tract (Blackwelder et al., 1998; Noftsger et al., 2000; Mena et al., 2001). Absorbed gossypol either is retained in organs such as the kidney and in muscle, or it is excreted via feces, urine, or milk (Lin et al., 1992; Gamboa et al., 2001a,b; Wan et al., 2003). If the contaminated tissues or milk are consumed by humans, they could have detrimental effects. Thus, it is necessary to pay close attention to gossypol concentrations in animal products, but as yet, little information has been made available on gossypol residues in milk. Only 2 studies have reported milk gossypol concentrations of dairy cows, but used only limited numbers of animals (Zhong, 2007) or inappropriate detection methods (Wan et al., 2003). Objectives of this study were to feed varying amounts of gossypol from WCS or CSM over a long period of time and determine effects on plasma and milk gossypol concentrations in lactating dairy cows.

MATERIALS AND METHODS

Experimental Design

Design and Treatments. The experimental design was a randomized complete block. Cows were blocked according to parity and milk yield or age at calving, and randomly assigned to 1 of 5 diets. Forty early lacta-

tion Holstein cows (86 ± 25 DIM) were assigned to 1 of 5 treatment diets (8 cows per diet) on the basis of parity, DIM, daily milk yield, and age at calving. The study period lasted 70 d. During a 10-d pretreatment period, all cows were fed a gossypol-free diet, which was also the control diet during the treatment period (control; Table 1). Experimental diets were fed as TMR and varied in their amounts of forage and concentrate to accommodate different amounts of CSM and WCS. Diets were formulated to be isonitrogenous and isoenergetic, and met the requirements of feeding standards of dairy cows [China NongYe HangYe Biaozhun/Tuijian-34 (China NY/t34, 2004)]. Detailed descriptions of dietary ingredients and nutrient composition are presented in Table 1.Cows were assigned to 1 of 5 treatment groups: no gossypol (control group), 91.15 mg of FG/kg from CSM (**CSM1** group), 117.31 mg of FG/kg from CSM (**CSM2** group), 385.43 mg of FG/kg from WCS (**WCS1** group), or 611.13 mg of FG/kg from WCS (**WCS2** group).

Animals and Housing. Cows were housed in open pens equipped with a neck rail. When feeding, all cows were tied alone to enable taking measurements of daily feed intakes from individual cows. All pens were identical in design, size, and location. Diets were fed twice daily at 0500 to 0830 and 1700 to 2030 h. Cows were milked twice daily at 0500 and 1700 h. Water was available ad libitum.

Measurements and Data

Feed Intake and Feed. Whole cottonseed and CSM were both from Yongqing, Hebei Province, China. Individual feed intakes were recorded daily during the trial period, and the TMR composition is presented in Table 1.

Milk Yield and Composition. Individual milk samples were collected on d 0, 15, 30, 45, and 60 of the experimental period, milk yields recorded, and milk analyzed for fat, protein, lactose, and SNF by infrared

Table 1. Ingredient and nutrient composition of diets

	Treatment[1]				
Composition	Control	CSM1	CSM2	WCS1	WCS2
Ingredient, g/100 g of DM					
Alfalfa hay	14.2	15.0	14.8	14.5	14.2
Corn straw	25.8	25.4	25.2	26.3	26.7
Corn	30.2	32.7	32.7	24.2	21.7
Wheat bran	6.4	1.4	1.4	6.6	6.7
Soybean meal	19.8	12.3	10.3	14.8	12.1
Cottonseed meal[2]	0.0	9.6	12.0	0.0	0.0
Whole cottonseed[3]	0.0	0.0	0.0	10.0	15.0
5% Premix[4]	3.0	3.0	3.0	3.0	3.0
Salt	0.6	0.6	0.6	0.6	0.6
Chemical, g/100 g of DM					
DM	90.34	90.68	90.71	90.30	90.27
NE_L,[5] Mcal/kg of DM	1.54	1.54	1.54	1.54	1.54
NDF	39.20	38.92	39.06	43.39	45.60
ADF	23.16	23.92	24.09	26.90	28.84
Fat	4.21	3.91	3.88	5.51	6.47
CP	15.70	15.70	15.70	15.70	15.70
Calcium	0.73	0.71	0.70	0.73	0.74
Phosphorus	0.81	0.85	0.86	0.84	0.86
TG, mg/kg of DM	0.00	651.97	839.08	816.66	1,294.88
FG, mg/kg of DM	0.00	91.15	117.31	385.43	611.13

[1]Cows were assigned to 1 of 5 treatment groups: no gossypol (control group), 91.15 mg of free gossypol (FG)/kg free from cottonseed meal (CSM, CSM1 group), 117.31 mg of FG/kg from CSM (CSM2 group), 385.43 mg of FG/kg from whole cottonseed (WCS, WCS1 group), or 611.13 mg of FG/kg FG WCS (WCS2 group).

[2]Consisted of DM (90.98%), CP (39.08%), ether extract (EE; 0.29%), ADF (22.76%), NDF (36.00%), FG (902.27 mg/kg), and total gossypol (TG; 6,453.66 mg/kg).

[3]Consisted of DM (90.38%), CP (21.22%), EE (18.39%), ADF (22.76%), NDF (36.00%), FG (3,666.89 mg/kg), and TG (7,769.52 mg/kg).

[4]Premix composition: vitamin A, 12,240 IU/kg; vitamin D_3, 3,670 IU/kg; vitamin E, 67,600 IU/kg; Fe, 33.65 mg/kg; Cu, 25.1 mg/kg; Mn, 30.59 mg/kg; Zn, 107.6 mg/kg; I, 1.10 mg/kg; Se, 0.67 mg/kg; Co, 0.54 mg/kg; Ca, 3.06–4.59 mg/kg; P, 0.92–1.99 mg/kg; and salt, 4.59–7.34 mg/kg.

[5]Calculated value (based on Ministry of Agriculture of the People's Republic of China, 2004).