6.22 on the DRB, RB and HMH treatments, respectively.

Although the steers in trial 2 were fed for only 88 days (due to a shortage of feed) there appeared to be faster gains and greater intakes on the high moisture barley rations.

Formaldehyde Treatment of Full-Fat Soy Flour to Protect the PUFA from Rumen Microbial Hydrogenation

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Story in Brief

Ground soy flour (GSF) was treated with formaldehyde (HCHO) for *in vitro*, tissue and organoleptic studies to determine if the polyunsaturated fatty acids (PUFA) of young, growing lamb's fat tissues can be increased. Excellent protection of linoleic acid, the major PUFA in GSF, from rumen microbial hydrogenation was obtained *in vitro* when the soy flour was treated with HCHO in small quantities (100 gm) and in large quantities (20 lb).

Rump, shoulder, omental and kidney knob fat from lambs fed the HCHO treated GSF supplement had ($P<.05$) more linoleic acid than lambs fed the untreated GSF supplement. There was no difference in linoleic acid content of loin fat between lambs fed the HCHO treated GSF ration and those fed the untreated GSF ration. Lambs fed the GSF rations had ($P<.05$) more linoleic acid in their loin fat than lambs fed SBM. There were no differences ($P>.05$) in daily feed consumption, feed/kg gain or average daily gain among any of the rations. No ($P>.05$) difference in meat flavor could be detected by a taste panel among any of the treatments. In sum, acceptable polyunsaturated meat from lambs was produced.

Introduction

Recently workers in Australia and in the U.S. have produced ruminant meat and milk products high in polyunsaturated fatty acids (PUFA)

by encapsulating polyunsaturated vegetable oils such as safflower or corn or soybean oil with a protein coat and then spraying this complex with formaldehyde (HCHO). This treated complex is resistant to microbial hydrogenation under the neutral conditions of the rumen, but upon entering the acid conditions of the abomasum, the complex is broken down releasing the PUFA for absorption. These unsaturated fats are absorbed from the small intestine and incorporated into the fat tissues.

Since soybeans have a natural protein-oil complex, it seemed conceivable that similar results might be achieved by soaking ground, whole soybeans (GSB) in HCHO. A previous trial was conducted in which HCHO treated and untreated GSB were fed as the supplemental protein source to young, growing lambs and no significant difference was observed in adipose tissue linoleic acid content between the two treatments. Those results may have been due to improper mixing or inadequate penetration of HCHO due to too large of a particle size. Therefore, this trial was conducted on ground, full-fat soy flour (GSF) which has a much smaller particle size. The purpose of this study was to determine by *in vitro* and animal tissue, growth and taste panel evaluation if the feeding of HCHO protected GSF to young lambs will result in increased levels of unsaturated fat in lamb fat tissue.

Methods

In Vitro Fermentations.

Approximately 100 gm samples of ground soy flour (GSF) were treated with 10.2 ml of 37 percent formaldehyde (HCHO) per 100 gm GSF along with sufficient water to cover the sample for either 2 or 6 hours. The excess water was poured off and the GSF was dried in a forced draft oven overnight. The dried soy flour was ground through a 1 mm screen in a Wiley mill and sub-samples were taken for *in vitro* incubation in a laboratory rumen fermentation by standard procedures previously used in this lab.

Soy flour was treated in 20 lb. batches with 10.2 ml of 37 percent HCHO per 100 gm GSF for 2 hrs for use in the animal study. The soy flour was dried, ground and sub-samples taken for *in vitro* incubation. Twenty ml samples were removed after various incubation times and freeze dried. The lipids were extracted, separated and measured.

Growth and Tissue Trial

Nine Western rams weighing an average of 33.5 kg were fed high concentrate finishing rations with the supplemental protein being (1) soybean meal (SBM), (2) untreated GSF or (3) GSF treated with 10.2 ml HCHO/100 gm GSF and soaked for 2 hr (10.2/2 hr). Ration compositions are shown in Table 1. The lambs were individually fed all they

Table 1. Ration Composition (Dry Matter Basis)

Ingredient	Soybean meal	Ground Soy Flour	Ground Soy Flour (10.2/2 hr)[1]
	%	%	%
Corn, ground	59.6	57.2	57.2
Soybean meal	9.2	--	--
Soy flour	--	11.5	11.5
Cottonseed hulls	29.8	29.8	29.8
Calcium carbonate	0.8	0.8	0.8
Salt	0.5	0.5	0.5
Vitamin A	+	+	+
Vitamin D	+	+	+

[1] 10.2 ml of 37% HCHO per 100 gm of soy flour, 2 hr. exposure.

could eat for 50 days. All lambs were slaughtered at approximately 100 lbs to obtain fat and tissue samples. The whole loins were removed and used for taste panel evaluation.

Taste Panel

One half of the loin was boned, the excess fat was removed, and loins from lambs receiving the same treatments composited and ground. The ground loin was baked to 160° F internally and served to a six member taste panel.

Results and Discussion

In Vitro Fermentation

Linoleic acid (18:2, 18 carbons long with 2 unsaturated positions) was markedly protected against microbial hydrogenation when GSF was treated with formaldehyde (HCHO) in small and large batches (Figure 1). Linoleic acid decreased only slightly over the 48-hr incubation period with rumen fluid when the GSF was treated with HCHO but decreased to almost 0 percent by the end of 12-24 hr. for the untreated GSF. Stearic acid, (18:0) the major end product of linoleic hydrogenation, increased only slightly over the incubation period when the GSF was treated with HCHO but showed a sharp increase in the untreated GSF samples corresponding to the sharp decline in linoleic acid. Since excellent protection of linoleic acid against ruminal activity was observed, increases in the linoleic acid content of the tissue lipids were expected.

Tissue Data

Linoleic acid (18:2) was ($P<.05$) higher (Table 2) in rump, shoulder, kidney knob and omental fat of lambs fed the HCHO treated GSF ration

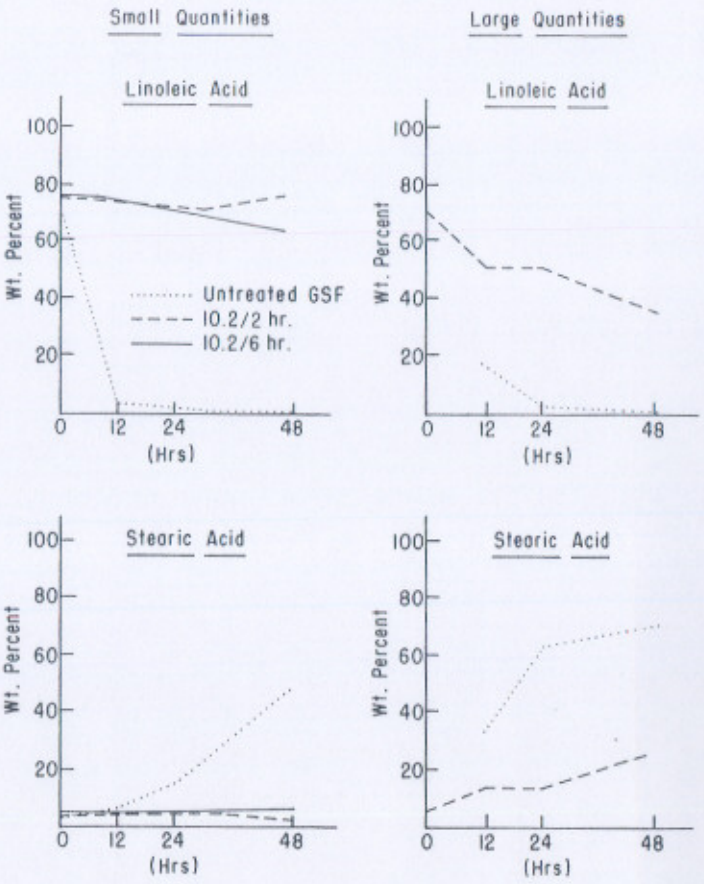

Figure 1. Weight percents of stearic and linoleic acids over a 48-hr. incubation period for untreated GSF or GSF treated with HCHO in small and large quantities.

than in lambs fed the untreated GSF ration. In addition, linoleic acid was ($P<.05$) higher in the fat tissues of lambs fed the untreated GSF ration as compared to lambs fed SBM. Myristic (14:0) and palmitic acids (16:0) were ($P<.05$) lower in the kidney fat of lambs fed the untreated GSF ration and palmitic acid was also ($P<.05$) lower in the kidney fat of lambs fed untreated GSF as compared to lambs fed SBM.

No significant differences among treatments were noted in stearic (18:0) or oleic (18:1) acids in any of the fat tissue sites. The fatty acid

Table 2. Weight Percents of the Major Fatty Acids in Selected Adipose Tissue Sites In Lambs Fed HCHO Treated and Untreated GSF

Rations[3]	14:0[1,2]	16:0	18:0	18:1	18:2
			Rump		
SBM	8.53[1]	23.44[1]	18.65[1]	40.54[1]	4.31[1]
GSF	10.96[1]	22.19[1]	19.17[1]	35.10[1]	6.82[2]
10.2/2 hr	5.91[1]	21.29[1]	19.83[1]	35.98[1]	11.86[3]
			Shoulder		
SBM	7.86[1]	25.81[1]	14.43[1]	40.83[1]	4.59[1]
GSF	6.02[1]	21.34[2]	16.20[1]	41.91[1]	9.28[2]
10.2/2 hr	5.69[1]	21.57[2]	15.28[1]	39.60[1]	11.51[3]
			Kidney		
SBM	5.92[1]	22.41[1]	30.57[1]	31.97[1]	4.94[1]
GSF	5.52[1]	20.14[2]	25.72[1]	31.93[1]	12.08[2]
10.2/2 hr	3.25[2]	17.17[3]	28.78[1]	31.57[1]	15.26[3]
			Omental		
SBM	8.84[1]	24.44[1]	23.58[1]	32.55[1]	5.96[1]
GSF	7.57[1]	20.38[2]	24.17[1]	29.56[1]	11.50[2]
10.2/2 hr	6.45[1]	18.86[2]	22.54[1]	28.76[1]	15.07[3]

[1] 14:0, Myristic; 16:0, palmitic; 18:0, stearic; 18:1, oleic 18:2, linoleic.
[2] 123: Means within columns with different superscripts differ significantly (P .05).
[3] SBM=Soybean meal; GSF=ground soy flour; 10.2/2 hr=10.2 ml HCHO per 100 gm GSF, 2 hr. exposure to HCHO.

Table 3. Weight Percents of the Major Fatty Acids In Loin Chops of Lambs on GSF Trial.

Rations	14:0[1,2]	16:0	18:0	18:1	18:2
SBM	4.88[1]	26.08[2]	14.29[1]	43.46[1]	5.65[1]
GSF	4.58[1]	23.68[1]	16.08[1]	38.61[1]	12.12[2]
10.2/2 hr.	4.11[1]	22.29[1]	15.95[1]	39.09[1]	13.56[2]

[1] See table 2 for fatty acid nomenclature.
[2] 123: Values in columns with different superscripts differ significantly (P<.05).

composition of loin fat (Table 3) did not differ in linoleic acid content between lambs fed the HCHO treated GSF ration and those fed the untreated GSF ration. However, the lambs fed the untreated GSF ration had (P<.05) more linoleic acid than lambs fed SBM. Palmitic acid was (P<.05) lower in the lambs fed treated and untreated GSF compared to lambs fed SBM. No differences were noted among treatments for myristic (14:0), stearic (18:0) or oleic (18:1) acids.

Growth Data

There were no significant differences among treatments for daily feed consumption, feed efficiency or average daily gain (Table 4). However, the lambs on the HCHO treated ration tended to have a poorer feed efficiency and daily gain than lambs fed untreated GSF or SBM.

Taste Panel Data

No differences in the flavor of ground loin among any of the treatment comparisons were apparent (Table 5). Cooking had no apparent effect on the fatty acid composition of the loin (Table 6).

Conclusion

With proper formaldehyde treatment and processing, the polyunsaturated fatty acids of whole fat soybeans can be protected from rumen microbial hydrogenation. This results in ruminant meat high in polyunsaturated fatty acids and which remains as desirable in flavor as meat from animals fed a conventional diet.

Table 4. Growth Performance Data on Lambs Fed Treated and Untreated Soy Flour

	Rations		
	SBM	GSF	10.2/2 hr.
No. of lambs	3	3	3
Days on trial	50	50	50
Average daily gain, lbs.[2]	.53[1]	.62[1]	.40[1]
Daily feed consumption/head, lbs.	3.04[1]	3.45[1]	3.08[1]
Feed required per lb. gain, lbs.	6.02[1]	5.65[1]	8.34[1]

[1] 1: Means within same row with same superscript do not statistically differ ($P \leq .05$).

Table 5. Taste Panel Data on Flavor of Ground Lamb

Comparison	Number of Comparisons	Number of Correct Responses[1]
SBM/GSF	24	9
SBM/2 hr	24	11
GSF/2 hr	20	10

[1] No significant differences in flavor ($P \geq .05$) among any of the comparisons.

Table 6. Fatty Acid Weight Percents of Cooked and Uncooked Ground Lamb Loins

Fatty Acids[1]	Rations[2]					
	SBM		GSF		10.2/2 hr.	
	Uncooked	*Cooked*	*Uncooked*	*Cooked*	*Uncooked*	*Cooked*
14:0	5.68	5.80	4.66	4.52	4.31	4.34
16:0	24.18	24.79	22.08	21.50	20.16	20.94
18:0	16.85	16.51	15.64	16.77	17.89	17.48
18:1	41.98	42.42	42.93	41.77	39.26	39.09
18:2	5.94	5.32	9.56	10.68	13.66	13.05

[1] See table 2 for fatty acid nomenclature.
[2] No statistical analysis was conducted as loins were composited according to rations.