Processing cottonseed to moderate fatty acid metabolism and improve milk production by dairy cows

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Introduction

From cottonseed (CS) . . . to processed CS feedstuffs.

Whole cottonseed (**WCS)** is a high-energy by-product with a well-balanced nutrient composition, which makes it a valuable commodity for high-producing dairy cows.

Nonetheless, its physical characteristics lead to storage and handling difficulties. Processing CS greatly improves flowability while maintaining nutritional benefits such as similar protein utilization and NDF effectiveness to WCS.

However, processing CS might modify the nutritional characteristics of the other major nutrient of WCS: fatty acids (**FA**). In particular, WCS has 53% linoleic acid, which can depress fiber digestibility and milk fat % and yield if in a free form.

There are limited data evaluating how processing of WCS affects free oil availability and resulting effects on ruminal fermentation, nutrient digestibility, and milk performance.

We hypothesized that increasing the particle size of the CS pellet (large pellet; **LP**) or diluting the feeding of a smaller pellet (**SP**) with delinted CS (**SPD,** 50:50 mix of SP and delinted CS) would limit the rate of CS oil release and consequently optimize digestibility of FA and fiber while maintaining milk fat production.

Field observations and potentially improved fat digestibility support the usage of SPD at about 90% of the feeding rate of WCS.

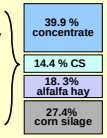
Objectives

- To determine the effects of feeding LP or SPD vs. SP or WCS on ruminal fermentation, in situ FA disappearance, nutrient digestibility, and milk FA profile.
- To evaluate lactation performance by dairy cows fed LP, SPD, or **SPD90** (50:50 mix of SP and mechanically delinted CS) compared to WCS.

Material and methods

A control diet was formulated using CS hulls, CS meal, tallow, and Megalac® to supply the same nutrients (NDF, 53%; CP, 22%; FA, 20%; ash, 4.0%; and NFC, 1.0%) as WCS. Six treatment diets were formulated:

CSH	CS hulls + CS meal + Megalac® and tallow
WCS	whole CS
SP	small CS pellets
LP	large CS pellets
SPD	½ SP, ½ partially delinted CS
SPD90	90% SPD, 10% Concentrate



The diet composition averaged 31.2% NDF, 18.1% CP, 5.9% FA, 7.0% ash and 37.7% NFC. The FA composition was similar for all diets: C16:0, 22%; C18:0, 2%; C18:1, 14%; and C18:2, 53%, except for CSH: C16:0, 32%; C18:0, 6%; C18:1, 28%; and C18:2, 20%.

Experiment 1: A 5 x 5 Latin square design with 3-wk periods was conducted using 5 rumen cannulated cows fed CSH, WCS, SP, LP, or SPD as treatments.

Experiment 2: Sixty cows averaging 105 DIM were fed the WCS diet for 2 wk and then assigned to one of the 4 following diets for 12 wk: WCS , LP, SPD, and SPD90.

Data were analyzed using PROC MIXED, with cow as a random effect. For experiment 2, data were covariate-adjusted and analyzed by repeated measures. When the diet x week effect was significant, the effect was partitioned using the SLICE option. Differences were deemed significant at $P<0.05$.

Results

Table 1. LS means for rumen fermentation in experiment 1.[1]

	CSH	WCS	SP	LP	SPD	SEM
pH	6.17	6.15	6.12	6.14	6.14	0.09
VFA, mM	103	102	104	103	102	3

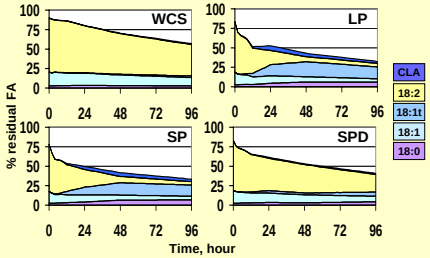
[1]CSH: CS hulls, CS meal, Megalac + tallow; WCS: whole linted cottonseed; SP: small CS pellets; LP: larger pelleted CS; SPD: ½ small CS pellets and ½ partially delinted CS.

Table 2. LS means of apparent nutrient digestibility in experiment 1.[1]

	CSH	WCS	SP	LP	SPD	SEM
OM	75.2	77.5	76.9	75.9	74.2	1.2
NDF	56.0	60.8	57.0	58.0	54.3	2.5
Total FA	78.8^{b}	81.1^{ab}	82.6^{a}	82.3^{a}	75.3^{c}	2.8

[1]CSH: CS hulls, CS meal, Megalac + tallow; WCS: whole linted cottonseed; SP: small CS pellets; LP: larger pelleted CS; SPD: ½ small CS pellets and ½ partially delinted CS.
^{a,b,c} $P < 0.05$.

Figure 1. Percentage of original C18 fatty acid isomers from WCS products remaining in situ in experiment 1.[1]



[1] WCS: whole linted cottonseed; SP: small CS pellets; LP: larger pelleted CS; SPD: ½ small CS pellets and ½ partially delinted CS. 18:0 = stearic acid; 18:1 = oleic acid; 18:1t = total *trans* 18:1; 18:2 = linoleic acid; CLA = total conjugated linoleic acids.

Table 3. LS means of milk fatty acid profile in experiment 1.[1]

	CSH	WCS	SP	LP	SPD	SEM
<16:0	21.7^{b}	24.4^{a}	22.8^{b}	22.1^{b}	24.1^{ab}	1.3
16:0	30.9^{a}	27.5^{b}	27.0^{b}	27.2^{b}	27.5^{b}	1.3
t-10 18:1	0.429^{ab}	0.316^{b}	0.508^{a}	0.511^{a}	0.295^{b}	0.059
t-11 18:1	3.23^{b}	3.79^{b}	6.58^{a}	6.24^{a}	3.97^{b}	0.81
c-9 18:1	21.4^{a}	18.6^{b}	16.5^{c}	16.9^{c}	18.1^{bc}	1.0
c-9, *c*-12 18:2	3.36^{d}	3.37^{d}	4.03^{b}	4.32^{a}	3.75^{c}	0.13
c-9, *t*-11 18::2	0.72^{b}	0.82^{b}	1.19^{a}	0.78^{b}	0.78^{b}	0.086
t-10, *c*-12 18:2	0.039^{bc}	0.025^{c}	0.063^{a}	0.055^{ab}	0.036^{bc}	0.012

[1]CSH: CS hulls, CS meal, Megalac + tallow; WCS: whole linted cottonseed; SP: small CS pellets; LP: larger pelleted CS; SPD: ½ small CS pellets and ½ partially delinted CS.
^{a,b,c} $P < 0.05$.

Table 4. LS means of performance in experiment 1.[1]

	CSH	WCS	SP	LP	SPD	SEM
DMI, kg/d	22.2	23.8	23.1	22.6	22.8	1.8
Milk, kg/d	42.7	40.5	40.9	39.9	40.6	2.6
Fat, %	2.69	3.11	2.79	2.84	2.92	0.35
Protein, %	2.96	3.09	3.08	3.12	3.12	0.08

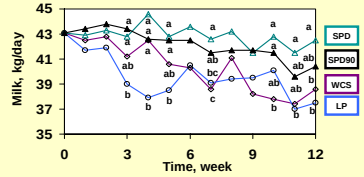
[1]CSH: CS hulls, CS meal, Megalac + tallow; WCS: whole linted cottonseed; SP: small CS pellets; LP: larger pelleted CS; SPD: ½ small CS pellets and ½ partially delinted CS.

Table 5. LS means of performance in experiment 2.[1]

	WCS	LP	SPD	SPD90	SEM
Milk fat, %	3.07^{a}	2.74^{b}	3.08^{a}	2.85^{b}	0.10
Milk protein, % [2]					
Primiparous	3.01^{b}	3.23^{a}	3.03^{b}	3.15^{a}	0.04
Multiparous	3.10	3.14	3.09	3.08	0.04
3.5% FCM, kg/d	35.0^{ab}	31.2^{b}	37.3^{a}	34.5^{ab}	1.8
BW change, kg/d	0.42^{ab}	0.61^{a}	0.35^{b}	0.40^{b}	0.12

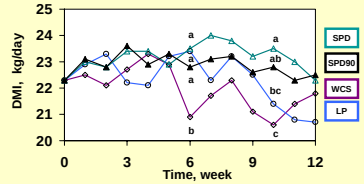
[1] WCS: whole linted cottonseed; SP: small CS pellets; LP: larger pelleted CS; SPD: ½ small CS pellets and ½ partially delinted CS; SPD90 = 90% SPD +10% concentrate.
[2] Diet x parity interaction ($P < 0.05$).
^{a,b,c} $P < 0.05$.

Figure 2. LS Means of milk production in experiment 2.[1]



[1] WCS: whole linted cottonseed; SP: small CS pellets; LP: larger pelleted CS; SPD: ½ small CS pellets and ½ partially delinted CS; SPD90 = 90% SPD +10% concentrate.
^{a,b,c} $P < 0.05$. SEM = 1.0.

Figure 3. LS Means of dry matter intake in experiment 2.[1]



[1] WCS: whole linted cottonseed; SP: small CS pellets; LP: larger pelleted CS; SPD: ½ small CS pellets and ½ partially delinted CS; SPD90 = 90% SPD +10% concentrate.
^{a,b,c} $P < 0.05$; SEM = 0.6.

Discussion

Processing of WCS did not impair ruminal fermentation (**Table 1**). There was no depression of NDF digestibility when processed CS were fed (**Table 2**). FA digestibility was significantly higher for SP and LP than CSH, probably because of tallow in the CSH treatment, which should be slightly less digestible than CS oil.

Because FA digestibility of SPD was lower than both SP and WCS, we propose that delinted cottonseed has lower FA digestibility than WCS or pelleted CS products, possibly from greater passage rate of intact or partially ruminated seeds.

In situ disappearance rate of FA from CS products was significantly faster with CS processing (data not shown). The residual FA in the bag were rapidly enriched with 18:2 biohydrogenation intermediates (trans 18:1, CLA; **Fig. 1**) with both SP and LP substrates, supporting no influence of pellet size on oil release kinetics and that both provided FA in a much more available form than the other products.

There was lower % of small and medium chain FA in milk from cows fed CSH, SP, or LP, attributable to inhibition of de novo milk FA synthesis (**Table 3**). In support of this conclusion, *trans* 18-carbon isomers were higher with SP and LP, even though all treatments except CSH had a similar dietary FA profile. Thus, appearance of *trans* isomers in situ is consistent with greater ruminal metabolism of free FA and subsequent metabolism.

No differences were observed for lactation performance for experiment 1 (**Table 4**). Nonetheless, we observed an inversion of milk fat:protein ratio with the CSH, SP and LP diets compared with WCS and SPD.

The negative effect of feeding free oil from pelleted CS was further demonstrated in the 12-wk lactation trial by a significant decrease in 3.5% FCM (**Table 5**) or milk production over time (**Fig 2**.) with the LP diet. Decrease in dry matter intake followed the same pattern as milk production over time (**Fig. 3.**).

Feeding SPD maintained comparable (SPD90) or higher (SPD) milk production over time and provided both handling and nutritional benefits compared with WCS.

Conclusion

Although having a lower FA digestibility, SPD appeared to minimize negative effects of free oil in the rumen from SP, explaining higher DMI and milk production than WCS or LP.

Abstract

Whole cottonseed is commonly added to dairy diets to provide energy, protein, and as a partial substitute for forage. For some feeding situations, however, handling problems limit their feasibility for use. Although pelleting and delinting processes overcome these problems, rapid release of free oil or lower total tract digestibility, respectively, can decrease their efficacy. In our study, a mix of pelleted and delinted cottonseed appeared to modify ruminal fatty acid metabolism, decreasing the risk of milk fat depression; dry matter intake and milk production tended to increase with time compared with conventional or pelleted cottonseeds. However, pelleting through a larger die appeared to provide no benefit.

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