Effect of whole cottonseed, heat-treated whole cottonseed and whole cottonseed plus lanolin on milk production and composition

W.A. Smith*
Department of Animal Science, University of Stellenbosch, Stellenbosch, 7600 Republic of South Africa

L.P. Vosloo
P.O. Box 6047, Uniedal, 7612 Republic of South Africa

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The study was conducted to determine the effect of whole cottonseed (WCS), heat-treated whole cottonseed (HWCS), and whole cottonseed plus lanolin (WCS + L) on feed intake, milk production and milk composition. Eight Holstein heifers in early lactation were fed total mixed diets containing 0% WCS (basal), 25% WCS (WCS), 25% heat-treated WCS (HWCS), or 25% WCS with 2% lanolin (WCS + L). The eight heifers were divided into two groups of four and were fed the four diets according to the prescription of a switch-over design. Periods consisted of a 21-day adaptation period followed by a 16-day experimental period after which cows were switched to the next treatment. Milk samples for analysis were collected every fourth day during the 16-day experimental period. Dry matter intakes did not differ significantly between treatments although cows which received the HWCS diets had the highest intake. Milk yield was increased significantly ($P < 0.05$) on the WCS and HWCS treatments with the highest milk production on the HWCS treatment. Milk fat percentage and yield were increased ($P < 0.01$) on the WCS, HWCS and WCS + L treatments. Milk fat yield on the HWCS treatment was also higher ($P < 0.05$) than on the WCS and WCS + L treatments. Milk protein content or yield was not affected by any of the treatments. Milk fatty acid composition was altered significantly by all cottonseed treatments. WCS increased ($P < 0.01$) the weight of C18 and C18:1 fatty acids. The higher ($P < 0.01$) C18:2 content of milk fat on the HWCS treatment indicated that heat treatment protected fat from hydrogenation in the rumen. The inclusion of whole cottonseed or heat-treated whole cottonseed in total mixed diets for lactating dairy cows should lead to higher milk and milk fat production.

Die studie is onderneem om die effek van heel katoensaad (HKS), hittebehandelde heel katoensaad (HHKS) en heel katoensaad met lanolien (HKS + L) op voerinname, melkproduksie en melksamestelling te ondersoek. Agt eerste-laktasie Holsteinverse is volgens 'n oorskakelproefontwerp vier volledige diëte gevoer wat 0% HKS (basaal), 25% HKS (HKS), 25% hittebehandelde HKS (HHKS) of 25% HKS met 2% lanolien (HKS + L) bevat het. Periodes het uit 'n 21-dae aanpassingsperiode gevolg deur 'n 16-dae eksperimentele periode bestaan waarna die koeie na die volgende behandeling oorgeskakel is. Melkmonsters vir ontleding is elke vierde dag gedurende die eksperimentele periode versamel. Hoewel die koeie wat die HHKS-dieet ontvang het die hoogste droëmateriaalinname gehad het, was daar geen betekenisvolle verskille tussen behandelings nie. Melkproduksie is betekenisvol ($P < 0.05$) op die HKS- en HHKS-behandelings verhoog met die hoogste melkproduksie op die HHKS-behandeling. Bottervetpersentasie en produksie is hoogs betekenisvol ($P < 0.01$) op die HKS-, HHKS- en HKS + L-behandelings verhoog. Bottervet-produksie op die HHKS-behandeling was betekenisvol ($P < 0.05$) hoër as op die HKS- en HHKS + L-behandelings. Melkproteïenpersentasie of produksie is nie deur enige van die behandelings beïnvloed nie. Die vetsuursamestelling van die bottervet is betekenisvol deur al die behandelings beïnvloed. Die HKS-behandeling het die massa van C18- en C18:1-vetsure verhoog ($P < 0.01$). Die hoër ($P < 0.01$) C18:2-inhoud van die bottervet op die HHKS-behandeling het daarop gedui dat die hittebehandeling vet in die rumen teen hidrogenering beskerm het. Die insluiting van heel katoensaad of hittebehandelde heel katoensaad in volledige diëte vir lakterende melkkoeie sal melk- en bottervet-produksie waarskynlik verhoog.

Keywords: Heat treatment, milk composition, milk production, whole cottonseed.

* Author to whom correspondence should be addressed.

Introduction

Whole cottonseed (WCS) has become an important ingredient in diets for high-producing dairy cows in South Africa in recent years. WCS contains on a dry matter (DM) basis high levels of energy (96% total digestible nutrients or 16.0 MJ ME/kg), protein (25%), acid detergent fibre (ADF) (26%) and fat (23.8%) (NRC, 1989). Because of its unique nutritive composition it offers great opportunity as an ingredient in diets for high-producing dairy cows which are invariably in a negative energy balance (De Peters *et al.*, 1985; Coppock *et al.*, 1987).

In a summary of 18 trials, Coppock *et al.* (1987) found no significant differences in DM intake when WCS was included up to 25% of the diet DM, and concluded that in most trials an increase in consumption of NE_l occurred. The studies summarized by Coppock *et al.* (1987) also suggested no depression in fibre digestibility when WCS was included up to 30% of diet DM. This implies that total fat intake with 30% WCS in the diet was not a restricting factor on rumen metabolism.

The inclusion of WCS in diets for high-producing dairy cows often increases milk production (Anderson *et al.*, 1979), with the most consistent effect being an increase in milk fat percentage in the order of 0.2 to 0.3 absolute per cent units or more (Linn, 1983; Coppock *et al.*, 1987).

Dry heating of WCS for 20 min decreased the disappearance of crude protein from dacron bags, kept in the rumen for 12 h, from 87 to 48% as the temperature was increased from 140 to 180 °C (Tagari *et al.*, 1986). Smith (1988) found that heat treatment of WCS with microwaves at 155 °C for 20 min reduced organic matter, fat and protein disappearance *in situ* with a fractional rumen outflow rate of 0.05/h from 53.9 to 33.2%, 60.7 to 35.1%, and from 64.6 to 39.3%, respectively. The heat-protected protein in the seed seems to protect the fat to the same extent against rumen metabolism as all fat globules are surrounded by a protein matrix. In most studies where heat-treated soybeans were compared with raw soybeans, milk production increased significantly ($P < 0.05$) (Owen *et al.*, 1985; Faldet & Satter, 1989) while milk fat production also increased in some of the studies.

It is possible that, at high levels of lipid supplementation, surface active agents may be beneficial in increasing fibre digestibility in the rumen (Devendra & Lewis, 1974). Tiedt & Truter (1952), as quoted by Becher (1957), suggested that the emulsifying ability of lanolin could possibly be attributed to its content of free alcohol and carboxyl groups. Lanolin contains 14 to 16% cholesterol (Von Bergen & Mauersberger, 1948) which could also contribute to its emulsifying potential (Truter, 1956). Conrad (1954), as quoted by Becher (1957), found that the hydroxy esters in lanolin also had emulsifying powers. Smith & Vosloo (1990) found that the apparent digestibility of neutral detergent fibre (NDF) and nitrogen increased significantly ($P < 0.05$) and highly significantly ($P < 0.01$) on a treatment containing 2% lanolin when compared with the control.

The objectives of this study were to determine the effect of WCS, heat-treated WCS, and WCS plus lanolin on feed intake, milk production and milk composition.

Materials and Methods

Eight Holstein heifers in early lactation were assigned randomly to a predetermined 4-diet sequence and they were fed total mixed diets containing 0% WCS (basal), 25% WCS (WCS), 25% heat-treated WCS (HWCS) or 25% WCS with 2% lanolin (WCS+L). WCS was heat treated with microwaves at 155 °C for 20 min (Smith, 1988). The eight heifers were fed according to switch-over design no. 5 of Patterson & Lucas (1962) in duplicate. Periods consisted of a 21-day adaptation period and a 16-day experimental period after which cows were switched to the next treatment.

Ingredient and chemical composition of total mixed diets are presented in Table 1. Cows were fed individually, twice daily at 06:00 and 18:00 to yield 5% orts. Feed offered and feed refusals were recorded daily while samples of diets were also collected daily and composited weekly. Feed and refusals were dried in a forced-air oven at 65 °C for DM determinations, milled and analysed for DM, Kjeldahl nitrogen (N), fibre, ether extract (EE), calcium (Ca) and phosphorus (P) (AOAC, 1985). NDF and ADF were determined according to Van Soest (1963) and Van Soest & Wine (1967). Metabolizable energy (ME) was calculated according to values published by Van der Merwe (1983).

Table 1 Ingredient and chemical composition of total mixed diets (90% DM basis)

Item		Diets			
		Basal	WCS	HWCS	WCS + L
Whole cottonseed	(%)	–	25.00	–	24.50
Heat-treated whole cottonseed	(%)	–	–	25.00	–
Lanolin	(%)	–	–	–	2.00
Cottonseed husks	(%)	4.75	–	–	–
Lucerne	(%)	30.00	30.00	30.00	29.40
Barley, rolled	(%)	45.10	33.20	33.20	32.54
Cottonseed oilcake	(%)	8.20	–	–	–
Urea	(%)	1.00	1.00	1.00	0.98
Molasses	(%)	6.80	6.80	6.80	6.66
Limestone	(%)	2.00	2.00	2.00	1.96
Monocalcium phosphate	(%)	0.45	0.30	0.30	0.29
Magnesium oxide	(%)	0.50	0.50	0.50	0.49
Salt	(%)	1.00	1.00	1.00	0.98
Trace elements + vitamins	(%)	0.20	0.20	0.20	0.20
Chemical analysis					
Crude protein	(%)	15.40	15.34	15.26	15.11
Crude fibre	(%)	14.47	14.42	14.31	14.20
Neutral detergent fibre	(%)	28.62	28.12	28.06	27.62
Acid detergent fibre	(%)	18.28	18.84	18.73	18.53
Ether extract	(%)	2.60	5.45	5.56	7.32
Metabolizable energy	(MJ/kg)[a]	9.62	10.00	10.00	9.80
Calcium	(%)	1.26	1.18	1.21	1.16
Phosphorus	(%)	0.41	0.40	0.30	0.39

[a] Calculated according to values by Van der Merwe (1983).

Cows were milked twice daily at 05:00 and 16:00 and milk yields were recorded at each milking. Milk samples were collected every fourth day during the 16-day experimental period. Milk samples consisted of a p.m. and a.m. composite for each cow. Composite milk samples were analysed immediately following the morning collection of each sample day for total nitrogen by Kjeldahl, total fat by the Gerber method (Atherton & Newlander, 1977) and total lactose by means of a near infra-red milkanalyser (Milkoscan 203). Fatty acid composition of milk fat was determined by lipid extraction, conversion to butyl esters and analysis by gas chromatography (Smith *et al.*, 1978).

Results and Discussion

Dry matter intakes, production, and composition of milk during the 16-day experimental period are presented in Table 2. Dry matter intakes did not differ significantly between treatments. In an examination of 18 trials Coppock *et al.* (1987) found no significant differences in dry matter intake when WCS was included up to 25% of diet dry matter. Milk yield was increased significantly ($P < 0.05$) on the HWCS treatment compared with the control treatment. In most studies where heat-treated soybeans were compared with raw soybeans, milk production increased significantly ($P < 0.05$) (Owen *et al.*, 1985; Faldet & Satter, 1989) and milk fat

Table 2 Performance of cows during the experimental period

Item		Diets				
		Basal	WCS	HWCS	WCS + L	SEM
Intake	(kg DM/day)					
Total diet		17.59	18.32	18.70	17.49	0.77
Production						
Milk	(kg/day)	21.86^{b}	22.96^{ab}	23.90^{a}	21.74^{b}	0.83
4% Fat corrected milk	(kg/day)	19.23^{b}	22.46^{ac}	24.00^{a}	21.15^{c}	0.85
Fat	(%)	3.20^{b}	3.86^{a}	4.02^{a}	3.82^{a}	0.09
Fat	(kg/day)	0.70^{c}	0.88^{ab}	0.96^{a}	0.83^{b}	0.04
Protein	(%)	2.95	2.95	2.99	2.90	0.06
Protein	(kg/day)	0.65^{b}	0.68^{ab}	0.72^{a}	0.63^{b}	0.03
Lactose	(%)	4.99^{a}	4.86^{ab}	4.82^{ab}	4.82^{b}	0.04
Lactose	(kg/day)	1.09	1.12	1.15	1.05	0.04
Total solids	(%)	12.03^{b}	12.55^{a}	12.66^{a}	12.40^{ab}	0.13
Total solids	(kg/day)	2.63^{b}	2.88^{ab}	3.03^{a}	2.70^{b}	0.11
Solids non-fat	(%)	8.83^{a}	8.69^{ab}	8.63^{b}	8.58^{b}	0.05
Solids non-fat	(kg/day)	1.93	2.00	2.06^{a}	1.87^{b}	0.08

$^{a-c}$ Means in the same row with different superscripts differ significantly ($P < 0.05$).

percentage also increased ($P < 0.05$) in some of the studies. Anderson *et al.* (1979) also reported an increase in milk production with cottonseed feeding. Milk fat percentage and yields of milk fat and 4% fat corrected milk (FCM) were increased ($P < 0.01$) by the inclusion of cottonseed, heat-treated cottonseed or cottonseed plus lanolin. Milk fat yield on the HWCS treatment was also significantly ($P < 0.05$) higher than on the WCS or WCS + L treatments. This is an important finding which indicates possible higher dietary lipid uptake from heat-treated cottonseed. Other workers (Smith *et al.*, 1981; Anderson *et al.*, 1982; Chalupa *et al.*, 1985; De Peters *et al.*, 1985) also reported increases in milk fat percentage and yield with cottonseed feeding. In the present study, milk protein content and yield was not decreased when WCS was added. Anderson *et al.* (1979), Smith *et al.* (1981) and De Peters *et al.* (1985) reported decreased milk protein percentage and yield with cottonseed feeding. The mechanism whereby supplementary fat, especially protected fat, sometimes depresses protein in milk has yet to be understood (Palmquist & Jenkins, 1980). Total milk solids increased ($P < 0.05$) with WCS feeding from 12.03 to 12.55% and from 12.03 to 12.66% ($P < 0.01$) with the feeding of heat-treated WCS. Solids non-fat content was significantly ($P < 0.01$) decreased on the HWCS and WCS + L diets. It was also decreased on the WCS treatment but not significantly ($P > 0.05$). The lower solids non-fat content with the inclusion of cottonseed is in agreement with that found by Smith *et al.* (1981) and De Peters *et al.* (1985).

The fatty acid composition of milk fat was altered significantly by the feeding of cottonseed (Table 3). The WCS treatment increased ($P < 0.01$) the weight percentage of stearic (C18) and oleic (C18:1) fatty acids while the HWCS treatment also increased ($P < 0.01$) the weight percentage of linoleic acid (C18:2). Because a lack of change in C18:2 concentration in milk fat indicates hydrogenation of polyunsaturated acids, as WCS is high in C18:2 (De Peters *et al.*, 1985), the higher C18:2 content of milk fat on the HWCS treatment indicated that the heat treatment protected fat from hydrogenation in the rumen. The increase in C18 and C18:1 and the decrease ($P < 0.05$) in short-chain fatty acids (C12 to C16) found when WCS was fed is in agreement with results of Smith *et al.* (1981) and De Peters *et al.* (1985).

Table 3 Fatty acid composition of milk fat during the experimental period

	Diets				
	Basal	WCS	HWCS	WCS + L	SEM
Fatty acids	Weight %				
12:0	3.91^{a}	1.54^{b}	1.56^{b}	1.55^{b}	0.09
14:0	11.69^{a}	6.50^{b}	6.42^{b}	6.77^{b}	0.37
15:0	1.43^{a}	0.76^{b}	0.66^{b}	1.53^{a}	0.06
16:0	31.81^{a}	28.04^{b}	17.71^{b}	28.33^{b}	0.32
16:1	1.14^{a}	0.52^{c}	0.46^{c}	0.70^{b}	0.05
16:3	0.20	0.24	0.15	0.11	0.05
16:4	0.26	0.15	0.15	0.19	0.06
17:0	0.80^{a}	0.52^{b}	0.52^{b}	0.59^{b}	0.02
18:0	10.64^{c}	20.84^{ab}	21.61^{a}	18.66^{b}	0.88
18:1	21.27^{b}	26.20^{a}	24.09^{a}	26.05^{a}	0.73
18:2	3.56^{b}	3.41^{b}	4.80^{a}	3.15^{b}	0.23
18:4	0.05	0.12	0.02	0.23	0.05
19:0	0.04	0.04	0.03	0.05	0.02
20:0	0.23	0.26	0.25	0.25	0.02
20:1	0.11	0.05	0.20	0.09	0.02
20:4	0.32	0.19	0.20	0.33	0.03
20:5	0.13	0.07	0.18	0.10	0.03

$^{a-c}$ Means in the same row with different superscripts differ significantly ($P < 0.01$).

Under the conditions of this study, increased yields of milk, milk fat, 4% FCM and total milk solids were found when WCS and heat-treated WCS were incorporated into diets of lactating dairy cows. When WCS and heat-treated WCS were fed, the yield of short-chain fatty acids was reduced and the yield of long-chain fatty acids (C18:0; C18:1) was increased in the milk fat. Heat-treated WCS also increased the yield of C18:2 fatty acids which indicated decreased hydrogenation in the rumen. There did not seem to be any advantage in adding lanolin to WCS.

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