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PRODUCTION OF CALCIUM SALTS OF FATTY ACID FROM SOAP-STOCK ON SEMI INDUSTRIAL SCALE AND ITS USE IN FINISHING RATIONS OF FRIESIAN BULLS

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SUMMARY

The study was carried out to produce protected fat from industrial waste (soap-stock) on semi-industrial scale and to evaluate two levels of supplementation in finishing diets of Friesian bulls. Ten tons of calcium salts of fatty acids (Ca-SFA) was prepared from soap-stock on semi-industrial scale. Protected fat was added in pellet form as a surplus at rate of 4% and 8% of total dry matter intake of basal diet (control) of 18 Friesian bulls (375 Kg) in three similar groups. Processing had not influenced the proportion of fatty acids of soap-stock and the product is almost insoluble at pH from 4-6.

Nutrient intake as TDN and DE ($P<0.05$) increased by about 15% for 4% Ca-SFA and 25% for 8% Ca-SFA groups. Final body weight, average daily gain and protein efficiency improved, however, energy utilization had not significantly affected by feeding Ca-SF supplemented rations.

Digestibilities of EE ,OM, DM and energy increased but digestibilities of crude protein, crude fiber and nitrogen free extract had not been affected by fat supplement. Also, ruminal fermentation and nitrogen metabolism were not significantly affected except an increase in protozoa count and a decrease in ruminal pH. Ca-SFA increased the concentrations of plasma lipids and calcium.

It could be concluded that soap-stock as an industrial waste could be efficiently utilized as animal feed to prepare protected fat which could be successfully incorporated up to 8 % of ration DM of fattening bulls.

Keywords: *Friesian bulls, calcium salts of fatty acids, growth.*

INTRODUCTION

Under intensive systems of ruminant production and the high genetic potential for meat and milk production, higher amount of cereal grains are required in the diets to increase digestible energy intake. This high need for energy, the negative effects of excess starch feeding and the increased availability of feed-grade fats has led to renewed interest in using fat to increase density of diets for ruminants (Palmquist and

Jenkins, 1980). On the other hand, fat addition to ruminant rations depresses fiber digestion in rumen (Palmquist and Jenkins, 1982). Such ruminal fermentation problems could be minimized, or even eliminated by feeding calcium salts of fatty acids (Jenkins, 1994).

Protected fat is widely used at commercial level for meat and milk production in the developed countries, but has a limited use in the developing ones because fat or oil used for preparing such protected fat are mostly consumed by human.

Soap-stock as one of the by-products of oil and soap industry containing not less than 60% fatty acid was used as a source of fatty acid to prepare protected fat in order to reduce fat feeding cost, environmental pollution and competition of human and animals on fat sources.

The aim of this study was to produce protected fat from industrial waste (soap-stock) on semi-industrial scale and to evaluate two levels of supplementation in finishing diets of Friesian bulls.

MATERIALS AND METHODS

Ten tons of calcium salts of fatty acids (Ca-SFA) was prepared from soap-stock on semi-industrial scale at Cairo Oil and Soap Co. Soap stock was treated with 14% calcium chloride (40% w: v solution) under steam at 130°F in a processing kettle. The product was skimmed and air dried at room temperature to about 80% DM. The produced Ca-SFA was pelletted in 1 cm length and 3 mm diameter. Chemical composition of Soap-stock and its calcium salts is shown in Table 1. Physical and chemical tests including solubility test (Sukhija and Palmquist 1990), fatty acid composition (A.O.C.S., 1973) were carried out. The relative low ether extract values does not represent the true fat content because such materials need to be analyzed as acidified ether extract as shown in Table 5.

Eighteen Friesian bulls of about 375 Kg body weight were randomly allotted into three similar groups. Animals were adapted for the experimental rations two weeks before data collection. Initial body weight of the experimental animals is shown in Table 8. Animals were weighed every two weeks during 120 day experimental period.

Concentrate mixture and rice straw were fed according to the biweekly body weight and body weight gain in amounts to cover the NRC (1984) recommended allowances. Pellets of the protected fat were added as a surplus to groups 2 and 3 at rate of 4% and 8% of total intake from concentrate and roughages. Animals were individually fed twice a day at 08.00 and 16.00 being watering at 10.00 and 17.30 p.m. Chemical composition of feed ingredients and experimental rations are shown in Tables 5 and 6.

Two sets of digestion trials were carried out at mid and end of the experimental period using three replicates applying the acid insoluble ash (AIA) technique (Van Keulen and Young, 1977). Therefore, each nutrient digestibility represented an average of six values. During the digestion trials, animals were fed at 06.30 and 18.30 hrs and grap samples were collected at 06.00 and 18.00 hr. Chemical composition and gross energy of feeds and feces were determined according to A.O.A.C. (1990). Acidified ether extract of Ca-SFA was determined as described by Drackley *et al.* (1985).

At the end of the last digestibility trials, rumen fluid samples were collected by

using stomach tube before and 4 hrs post feeding for two consecutive days. Ruminal pH, total VFA's concentrations (Kromann *et al.*, 1967), molar proportions of VFA's (Erwin *et al.*, 1961), nitrogen fractions (A.O.A.C., 1990), microbial protein (Shultz and Schultz, 1970), ammonia-N (Conway, 1978), protozoa count (Abou El-Naga (1967), total fatty acids (A.O.C.S., 1973) and free fatty acids (Itaya and Ui, 1965) were determined.

Blood samples were withdrawn from the left jugular vein of the same three replicates at the end of the last digestion trials, before morning meal. Red and white blood cells were counted in whole blood samples. Plasma total lipids, triglycerides and cholesterol were determined using commercial kits (Biomerieux 69280 Marcy-1, Etoile, France®). Free fatty acids (Itaya and Ui, 1965) and calcium (A.O.A.C., 1990) were also determined.

Statistical analysis was carried out using MSTATC (1989). Digestibility and performance data were analyzed as one-way analysis of variance according to the following model : $Y=\mu + x_i + e_{ij}$

Where:

Y= observation

μ= mean

x_i the effect of treatment for 1=1-3, 1 control, 2 = 4% CaSFA and 3 = 8 % CaSFA

e_{ij} = experimental error

Rumen and blood data were statistically analyzed as two-way analysis of variance according to the following model : $Y= \mu + x_i + x_j + x_{ij} + e_{ijk}$

Where:

Y= observation

μ= mean

x_i the effect of treatment for 1=1-3, 1 control, 2 = 4% CaSFA and 3 = 8 % CaSFA

x_j the effect of sampling time for 1=1-2 1 before feeding and 2 = 4 hrs post feeding

e_{ijk} = experimental error

Duncan's Multiple Range Test (Duncan, 1955) was used to separate the means when the main effect was significant.

RESULTS AND DISCUSSION

In comparison with soap stock, the product contained less organic matter and more ash mainly calcium due to calcium chloride treatment of soap during the processing practices. The low EE in the product (calcium soap) was a result of washing off for un-saponified fatty acids and non saponified materials from soap-stock which improved the quality of the product compared to the soap-stock, the original raw material (Table 1).

Minor differences in fatty acid composition were observed due to preparation process as a decrease in the short chain and an increase in long chain fatty acids. Generally, processing had not influenced the proportion of fatty acids of soap-stock as shown in Table 2.

Table 1. Comparative composition of soap-stock and its calcium salt

Item	Soap-stock	Calcium salt of soap-stock
Dry matter, %	69.54	97.00
DM composition, %		
Organic matter	93.56	88.34
Ether extract	12.44	5.16
Ash	6.44	11.66
Calcium	0.68	9.45
Sodium	5.53	0.55
Energy kcal/g	8.00	8.14
Fatty acid composition, %		
Total fatty acids	81.12	84.24
Saponified fatty acids	78.79	83.18
Un-saponified fatty acids	2.33	1.06
Non saponified materials	10.11	4.10

Table 2. Fatty acid composition, % of soap stock and its calcium salt

Item		Soap-stock	Calcium salt of Soap-stock
Caproic	C6:0	2	0
Cabrilic	C8:0	21	20
Cabric	C10:0	27	26
Lauric	C12:0	1	1
Myristic	C14:0	2	2
Palmitic	C16:0	4	5
Stearic	C18:0	8	9
Oleic	C18:1	19	20
Linoleic	C18:2	14	15
Linoleinic	C18:3	2	2

Physical proprieties of the calcium salt of soap stock fatty acids are presented in Table 3. The tests showed that the product was not soluble in either water or alcohol but was soluble in HCl at pH values of 2 to 3 . The solubility test proved that the product is almost insoluble at pH from 4-6 at different soaking time up to 12 h.. At lower pH (2-3), about 80% of the soap was soluble (Table 4). This might indicate that the product could be insoluble in the rumen environment but soluble in abomasum. Sukhija and Palmquist (1990) found that Ca-SFA of palm fatty acids was stable at pH = 5.5, dissociation was recorded to be less than 10% at pH = 5.5, less than 5 at pH=6 and about 1% at pH=6.5.

Chemical composition of the ingredients (Table 5) and composition of the experimental rations (Table 6) showed that the three rations were comparable in nutrient contents except the EE which was higher in the treatment ration, being 8.93% for the 4% Ca-SFA and 11.93% for the 8% Ca-SFA supplemented ration.

Table 3. Physical proprieties of the calcium salt of soap stock fatty acids

Trait	
Color	Yellow
Form	Pellets
Pellet length	1-1.5 cm
Diameter	3 mm
Solubility in water	Insoluble
Solubility in HCl acid (pH 2-3)	Soluble
Solubility in ether	Insoluble

Table 4. Effect of time and pH on the solubility (%) of the calcium salt of soap stock at 25°C

PH	Hours						
	0	2	4	6	8	10	12
2	0	60	70	75	80	82	88
3	0	56	60	63	77	78	80
4	0	1	3	3	3	4	6
6	0	1	2	2	2	3	3

Table 5. Chemical composition of the experimental ingredients

Item	Concentrate mixture	Rice straw	Ca-SFA
Dry matter,%	90.20	93.00	97.00
Dry matter composition, %			
Organic matter	91.10	75.10	88.34
Crude protein	15.50	3.51	0
Crude fiber	15.47	31.60	0
Ether extract	8.30	1.19	88.34
N-free extract	51.83	38.80	0
Ash	8.90	24.90	11.66
Energy, kcal/ kg	4275	3580	8144

Table 6. Composition of the experimental rations

Item	Control	4% Ca-SFA	8% CaSFA
Ingredient, %			
Concentrate mixture	64.03	61.80	59.84
Rice straw	35.97	34.36	32.72
Ca-SFA	-	3.84	7.44
Chemical composition, %			
Dry matter	91.11	93.14	91.63
Dry matter composition			
Organic matter	85.34	85.49	85.65
Crude protein	11.18	10.78	10.43
Crude fiber	21.28	20.42	19.58
Ether extract	5.74	8.93	11.93
N-free extract	47.14	45.36	43.71
Ash	14.66	14.51	14.35

Dry matter intake by the treated groups increased by about 4 % and 8% which are the same ratios of fat addition. However, energy as DE or TDN intakes were higher ($P<0.05$) for the fat supplemented groups than the control one by about 15% for 4% Ca-SFA and 25% for 8% Ca-SF groups (Table 7). This increase in energy intake could indicate the positive effect of fat addition on energetic value of the fat supplemented diets (Table 9). The effect of added fat on energy intake is variable among studies. Added fat sometimes increases digestible energy intake less than expected when added fat is poorly digested or when added fat reduces digestibility of the basal diet due to the inhibition of fiber digestion in the rumen (Jenkins, 1994).

Table 7. Dry matter, energy and protein intakes by the experimental groups

Item	Control	4% Ca-SFA	8% Ca-SFA	SE
Dry matter intake, Kg/h/day				
Concentrate mixture	7.37	7.41	7.48	
Rice straw	4.14	4.12	4.09	
Ca-SFA	0.00	0.46	0.93	
Total	11.51	11.99	12.50	0.03
DM intake, Kg/100 Kg	2.71^{c}	2.80^{b}	2.89^{a}	0.02
DM intake, g/ Kg $W^{0.75}$	123^{c}	127^{b}	132^{a}	14
Roughage, %	35.99^{a}	34.36^{b}	32.75^{c}	0.06
Digestible energy intake				
M cal /h/day	31.69^{c}	37.33^{b}	41.18^{a}	0.39
M cal/ 100 Kg BW	7.47^{c}	8.70^{b}	9.52^{a}	0.09
M cal/ Kg $W^{0.75}$	339^{c}	396^{b}	434^{a}	4
TDN intake				
Kg / h/day	7.02^{c}	8.08^{b}	8.94^{a}	0.07
Kg / 100 Kg BW	1.66^{c}	1.88^{b}	2.07^{a}	0.02
G/ Kg $W^{0.75}$	75.1^{c}	85.7^{b}	94.3^{a}	0.8
DCP intake				
G / h/day	771	778	750	20
G / 100 Kg BW	182	181	180	10
G/ Kg $W^{0.75}$	8.25	8.25	8.23	0.22

^{a,b,c} Means in the same row having different superscripts differ ($P<0.05$)

Feeding fat supplemented rations during 120 day-finishing period increased final body weight, total weight gain and average daily gain (Table 8). The increase was not proportional with the increase in dietary fat level (Ngidi *et al.*, 1990). The development in body weight is illustrated in Figure 1. The difference among the experimental groups was not obvious before 45 day, then the 8%-Ca-SFA group showed heaviest body weight, followed by the 4%-Ca-SFA group more than control.

Adding fat did not improve feed conversion ratio as energy units required to produce 1 Kg gain. This could be attributed to that the high energy intake from the fat supplemented rations had not been met by comparable increase in body weight. White *et al.* (1992) found that efficiency of steers was not affected by fat supplement.

Digestible protein conversion to gain was better in the fat supplemented group than the unsupplemented one. It could refer to that dietary fat could compensate and save dietary protein (Wu *et al.*, 1991).

Table 8. Body weight gain and feed conversion ratio of the experimental groups

Item	Control	4% Ca-SFA	8% Ca-SFA	SE
Initial body weight, Kg	375	374	374	2
Final body weight, Kg	474	485	491	2
Gain, Kg	99	111	117	3
Average daily gain, g/h/day	824	927	979	29
Feed conversion ratio				
DM , Kg / Kg gain	14.07	13.00	12.80	0.44
DE, Mcal / Kg gain	38.74	40.47	42.15	0.75
TDN, Kg / Kg gain	8.59	8.77	9.16	0.31
DCP, g / Kg gain	945	844	799	41

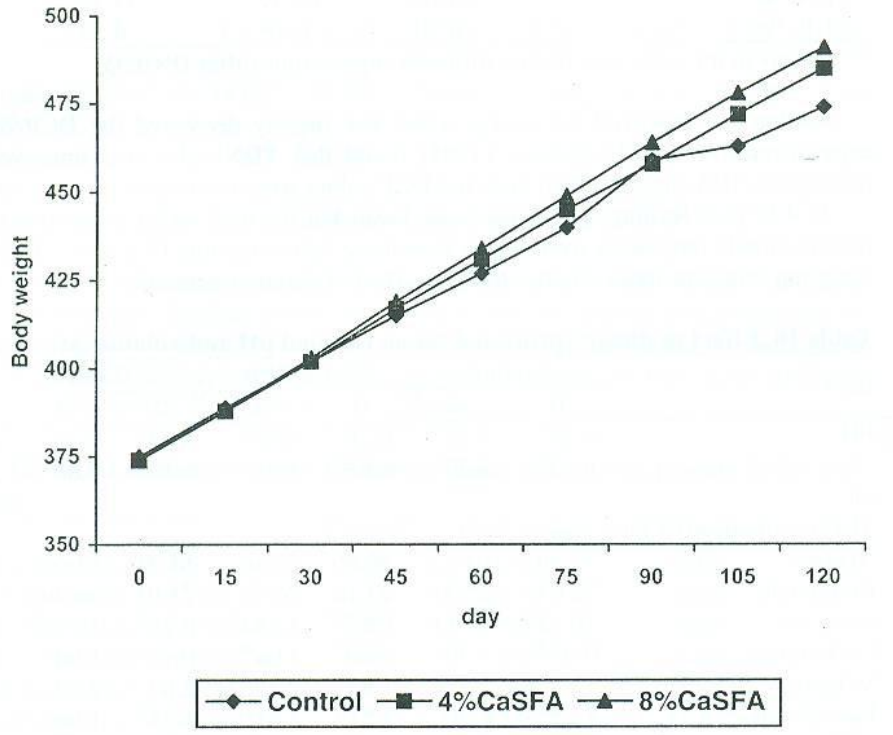

Figure 1. Body weight change during the 120 day experimental period

Fat supplement increased the digestibility of ether extract which resulted in higher digestibility of OM, DM and energy. Digestibilities of crude protein, crude fiber and nitrogen free extract were not affected by fat supplement (Table 9) . The high EE digestibility of fat supplemented rations might be due to the high digestibility of added dietary fat (El-Bedawy *et al.*, 1994). Crude fiber was not affected by added fat which could indicate that added fat was protected and did not affect the cellulolytic activity in the rumen.

Table 9. Effect of dietary protected fat on nutrient digestibilities by the experimental groups

Item	Control	4% Ca-SFA	8% Ca-SFA	SE
Nutrient digestibility, %				
Dry matter	63.71^{b}	65.74^{ab}	67.36^{a}	0.23
Organic matter	66.77^{b}	69.04^{a}	70.26^{a}	0.73
Crude protein	64.01	64.02	63.90	1.52
Crude fiber	59.27	59.42	59.28	0.77
Ether extract	70.64^{b}	83.88^{a}	83.54^{a}	1.06
N-free extract	70.59	72.10	73.45	1.66
Energy	69.13^{b}	75.15^{a}	77.04^{a}	0.79
Nutritive value				
DE Mcal/Kg DM	2.76^{c}	3.11^{b}	3.30^{a}	0.03
TDN, %	61.05^{c}	67.39^{b}	71.56^{a}	0.64
DCP, %	6.70	6.49	6.25	0.17

^{a,b,c} Means in the same row having different superscripts differ (P<0.05)

Adding fat improved the energy value but slightly decreased the DCP of the experimental rations. El-Bedawy (1995) found that TDN value was improved by feeding Ca-SFA supplemented diets but DCP values were not improved.

At 4 hr post feeding, pH values were lower but the total molar proportion of all rumen volatile fatty acids were higher than those before feeding (Table 10). Effect of sampling time was more obvious than the effect of dietary treatment.

Table 10. Effect of dietary protected fat on ruminal pH and volatile fatty acids

Item	Control		4% Ca-SFA		8% Ca-SFA		SE
	0	4	0	4	0	4	
PH	6.24^{a}	5.71^{b}	6.26^{a}	5.68^{b}	6.35^{a}	5.78^{b}	0.14
	6.85^{b}	8.27^{a}	6.83^{b}	8.11^{a}	6.69^{b}	7.80^{ab}	0.38
ml							
Molar proportion of fatty acids							
Acetate	54.86	63.12	56.66	52.46	55.71	61.62	3.52
Propionate	22.64	25.41	23.16	26.51	25.01	28.49	3.05
Butyrate	10.12^{cd}	13.11^{a}	9.65^{cd}	12.43^{ab}	8.76^{b}	10.95^{bc}	0.57
Iso-butyrate	0.95^{ab}	1.30^{a}	0.90^{b}	1.04^{ab}	0.95^{ab}	1.08^{ab}	0.12
Valerate	1.82	2.22	1.93	2.57	2.07	2.67	0.29
Iso-valerate	1.25^{b}	1.70^{a}	1.21^{b}	1.61^{a}	1.25^{b}	1.66^{a}	0.11
A/P ratio	2.66	2.69	2.73	2.57	2.55	2.44	0.43

^{a,b,c,d} Means in the same row having different superscripts differ (P<0.05)

Adding dietary fat did not affect nitrogen metabolism in the rumen as shown in Table 11. Ruminal protozoa count was higher for fat supplemented groups and at 4 h post feeding than that before feeding. However, dietary supplementation of sunflower seed oil (6% of DM) to sheep dramatically reduced protozoa numbers in rumen fluid within 5 days from approximately one million to fewer than 200,000/ml (Ivan *et al.*, 2001).

Table 11. Effect of dietary protected fat on ruminal nitrogen, fatty acids and protozoa count.

Item	Control		4% Ca-SFA		8% Ca-SFA		SE
	0	4	0	4	0	4	
Total nitrogen,mg/100 ml	204	219	203	218	200	218	8
Non protein nitrogen, mg/100 ml	72^{b}	83^{a}	73^{b}	83^{a}	73^{b}	82^{a}	3
Ammonia nitrogen, mg/100 ml	13^{b}	18^{a}	12^{b}	18^{a}	12^{b}	17^{a}	1
True protein nitrogen, mg/100 ml	132	136	131	136	128	136	7
Microbial protein nitrogen, mg/100 ml	82	84	87	94	84	95	5
Protozoa count x 10^3/ml	4.12^{c}	4.74^{b}	4.80^{b}	5.76^{a}	4.96^{b}	5.89^{a}	0.21
Total fatty acids mg/gDM	14.00^{c}	17.80^{bc}	20.98^{bc}	32.05^{b}	31.40^{b}	52.40^{a}	5.40
Free fatty acids, m mol/l	4.00^{ab}	2.97^{b}	4.51^{a}	4.06^{ab}	5.94^{a}	4.94^{a}	0.33

[a,b] Means in the same row having different superscripts differ ($P<0.05$)

Red blood cell count increased by feeding fat while white blood cell count showed no change. Feeding protected fat increased the plasma concentrations of lipids and calcium (Table 12). Palmquist and Conrad (1978) attributed the high blood plasma lipids of fat supplemented cows to the greater quantity of fatty acids absorbed from fat supplemented diets than the control ones.

Table 12. Effect of dietary protected fat on blood cell counts, plasma lipids and calcium

Item	Control	4% Ca-SFA	8% Ca-SFA	SE
Red blood cells x 10^6/ml	5.66	6.00	6.03	0.04
White blood cells x 10^3/ml	6.33	6.30	6.30	0.20
Plasma total lipids, mg/100 ml	509^{b}	581^{a}	596^{a}	14
Plasma triglycerides, mg/100 ml	65^{b}	120^{a}	134^{a}	8
Plasma cholesterol, mg/100 ml	196^{b}	289^{a}	300^{a}	10
Plasma free FA, μ M/100 ml	19.31^{c}	32.02^{b}	38.83^{a}	1.38
Plasma calcium, mg/100 ml	9.23^{c}	10.90^{b}	11.62^{a}	0.24

It could be concluded that soap stock as an industrial waste could be efficiently utilized as animal feed to prepare protected fat which could be successfully incorporated in rations of fattening bull up to 8 % of dry matter.

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إنتاج الدهن المحمى محليا من مخلفات تكرير الزيوت (الصوب ستوك) على النطاق شبه الصناعى واستخدامه فى علائق التهيئة لعجول التسمين الفريزيان

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أجريت هذه الدراسة بهدف إنتاج دهن محمى من مخلفات تكرير الزيوت (الصوب ستوك) على نطاق شبه صناعي وتقييم المنتج فى علائق التهيئة لعجول الفريزيان.

حضرت١٠ طن من أملاح الكالسيوم للأحماض الدهنية في المخلف، و أضيف المنتج فى علائق ١٨ عجل تسمين فريزيان فى بمستوى صفر ، ٤% و ٨% من المادة الجافة المأكولة.

قسمت العجول عشوائيا الى ثلاثة مجموعات متشابهة متوسط أوزانها ٣٧٥ كجم واستمرت التجربة لمدة ١٢٠ يوما وصلت الى وزن نهائى يتراوح من ٤٧٤ الى ٤٩١ كجم .

أظهرت النتائج ثبات المنتج وعدم ذوبانه فى درجة حموضة ٦,٤ ، وقد أدت التغذية على العلائق المحتوية على الدهن المحمى زيادة فى معاملات هضم مستخلص الأثير والمادة العضوية والمادة الجافة والطاقة و لم تتأثر معاملات هضم البروتين الخام والألياف الخام والمستخلص الخالي من النتروجين. كما لم تؤثر إضافة الدهن المحمى على تخمرات الكرش ولا تمثيل النتروجين به بينما أدت الى زيادة فى ليبدات وكالسيوم البلازما.

تحسن المأكول معنويا بنسبة ١٥% فى المجموعات المغذاة على الدهن المحمى بمستوى ٤% وبنسبة ٢٥ % للمستوى ٨% ، كما حسنت إضافة الدهن المحمى من الوزن النهائي و معدل الزيادة اليومية وكفاءة الاستفادة من البروتين، بينما لم تؤثر إضافة الدهن الى تحسن فى كفاءة الاستفادة من الطاقة.

يمكن استنتاج صلاحية استخدام مخلفات تكرير الزيوت (الصوب ستوك) فى الإنتاج المحلى لدهون محمية على صورة أملاح الكالسيوم للأحماض الدهنية واستخدام المنتج كإضافة دهنية فى علائق التهيئة لعجول التسمين الفريزيان بنسبة تصل الى ٨% من المادة الجافة