

乳中游離脂肪酸、脂肪酸數據 之應用

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一、乳中游離脂肪酸數據 之應用

爲什麼要測牛乳游離脂肪酸含量？


- 牛乳品質：游離脂肪酸含量越高，越容易**酸敗**。

Table 3. Effect of agitation and low temperature storage on free fatty acids, acid degree value and lipid peroxidation in milks of different species of animals.

Quality parameters	Control	Agitation (43 °C)	Low temperature storage (10 °C)
	Cow milk		
Free fatty acid (micro mol/ liter)	4401 ± 125	4871 ± 190	2128 ± 154
Acid degree value (µl/ 100 g of N base)	635 ± 10	1020 ± 23	430 ± 20
Peroxide value (micro mol/ liter)	588 ± 50	1091 ± 75	400 ± 23

影響因素(1)-擠乳系統

Table 4. Mean FFA level before and after passing through a conventional or an AM system

Milking system	n		mean FFA before (mmol/100 g fat)	mean FFA after (mmol/100 g fat)	increase FFA (mmol/100 g fat)
Test 1					
Conventional	12		0.43 ^a	0.50 ^a	0.07 ^a
Day 1	4	傳統	0.48	0.53	 生乳經過擠乳系統增加游離脂肪酸的量
Day 2	4	擠乳	0.36	0.41	
Day 3	4	系統	0.45	0.56	
AM brand 1	12		0.42 ^a	0.58 ^b	0.16 ^b
Day 1	4	自動	0.47	0.58	傳送管線空氣對生乳流量比例自動系統(8-10:1)大於傳統系統(3:1)
Day 2	4	擠乳	0.36	0.42	
Day	4	系統	0.45	0.63	
Test 2					
Conventional	8		0.58 ^a	0.65 ^a	0.07 ^a
AM brand 2	8		0.45 ^b	0.65 ^a	0.21 ^b

Different superscripts mean significant difference ($P < 0.05$), n = number of tests, 4 tests per day, figures with superscripts are least square means.

(Slaghuis et al., 2004; EU project *Implications of the introduction of automatic milking on dairy farms* (QLK5 -2000-31006))

影響因素(1)-擠乳系統

Table 3. Mean values of the determined parameters in relation to milking technology for 150 milk samples

Parameter	Automatic milking system	Milking parlour	Pipeline milking in stalls
n	10	97	43
FFA (mmol 100 g ⁻¹) 游離脂肪酸含量	1.54	2.15	**3.88
SCC (10 ³ ml ⁻¹)	237	283	289
TBC (CFU ml ⁻¹)	17 781	17 170	11 631
PLiBC (CFU ml ⁻¹)	560	607	696

For the abbreviations see Table 2, ** difference at significance level of $P < 0.01$

J Agrobiol 28(1): 49–54, 2011

影響因素(2)-擠乳頻率

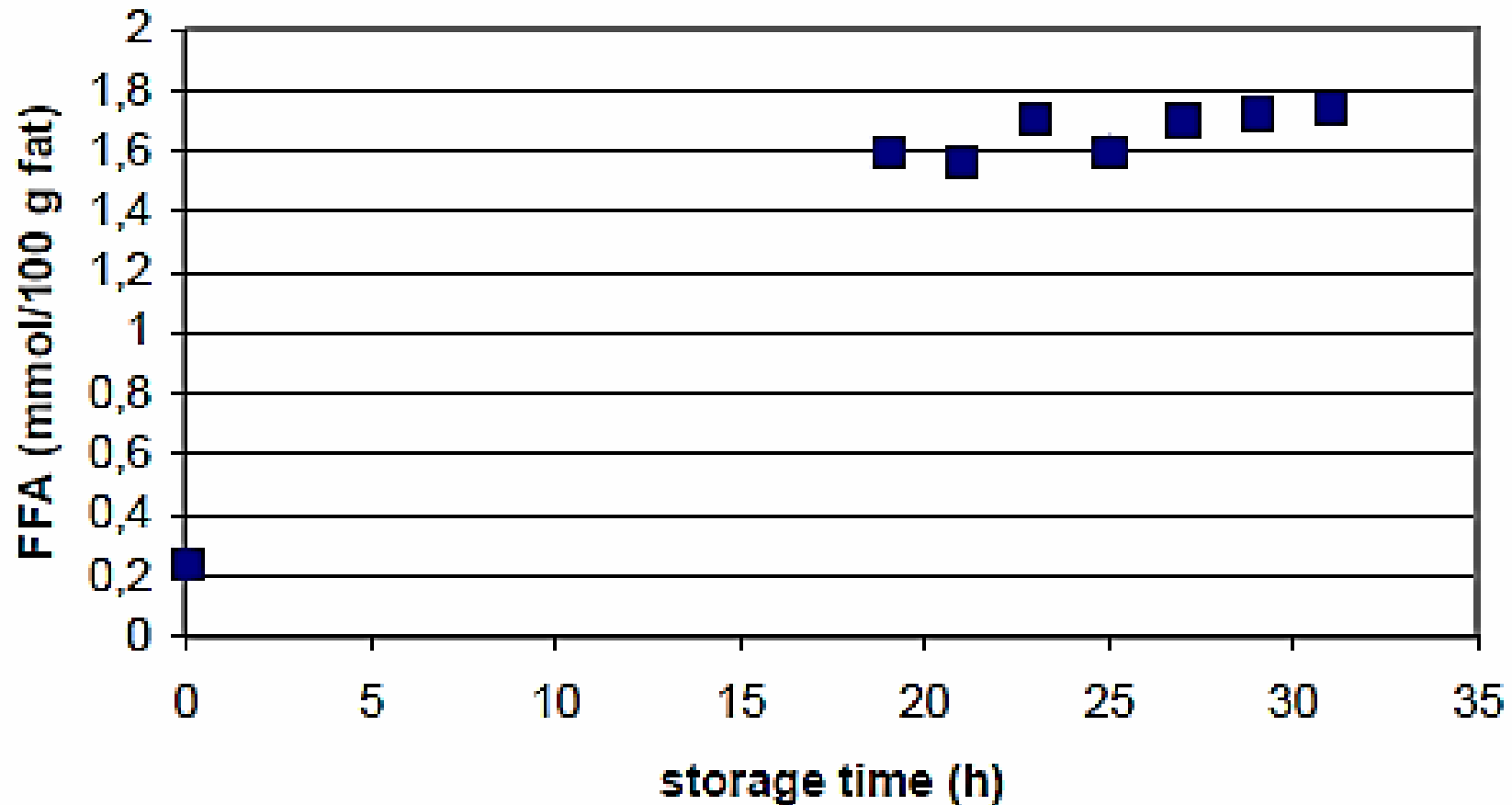
Table 9. Effect of milking interval on FFA contents (meq/100 g fat) in raw milk after 0 hours and 24 hours storage after sampling.

Interval (h)	擠乳間隔 時間 (小時)	4	8	12
0 hours		0.20 ^a	0.19 ^{ab}	0.15 ^b
24 hours		1.23 ^a	0.71 ^b	0.42 ^c
Delta FFA		0.97 ^a	0.49 ^b	0.25 ^c
Milk yield (kg/milking)		6.0 ^a	11.7 ^b	16.9 ^c

^{a,b,c} statistically significant difference on the same row P<0.05)

(Slaghuis et al., 2004; EU project *Implications of the introduction of automatic milking on dairy farms* (QLK5 -2000-31006))

影響因素(3)-生乳4°C貯存時間



(Slaghuis et al., 2004; EU project *Implications of the introduction of automatic milking on dairy farms* (QLK5 -2000-31006))

影響因素(4)-生乳過度攪動

Table 4 Variance components recorded within and between cows in Experiment 1 for free fatty acid (FFA) concentrations in milk samples: preserved immediately on collection (L0), preserved after 24 h (L24), and damaged by bubbling air through milk sample for 4 min and preserved 24 h (D24) after collection. All milk samples for FFA analyses were stored at 4°C.

Sample	Mean FFA concentration (mmol/100 g fat)	Variance component ¹		Coefficient of variation (%)		
		Within cow	Between cow	Within cow	Between cow	Total
L0	0.179	0.002	0.001	21.3	27.8	49.2
L24	0.308	0.006	0.004	25.0	32.9	57.9
D24	0.813	0.037	0.060	23.6	38.2	61.8

¹All variance components significantly different ($P < 0.001$) from zero.

New Zealand Journal of Agricultural Research, 2005, Vol. 48: 301–310

影響因素(5)-生乳暴露較高溫度

		Lipolysis. mequiv. FFA/100 g fat per 22 h	
Activation treatments*		I‡	II‡ (為對照組幾倍)
Trial 3 (n = 10)	U 對照組4°C 儲	0.37 ± 0.22	1
	T15 存	0.88 ± 0.52	2.4 ± 0.5
	T30	2.76 ± 1.46	8.1 ± 3.5

T15：5°C 生乳加溫到15°C 再立即冷卻到4°C ， 4°C 儲存22小時；

T30：5°C 生乳加 *Journal of Dairy Research* (1989), 56, 699-709 °C 儲存22小時。

影響因素(6)-乳牛餵飽和脂肪

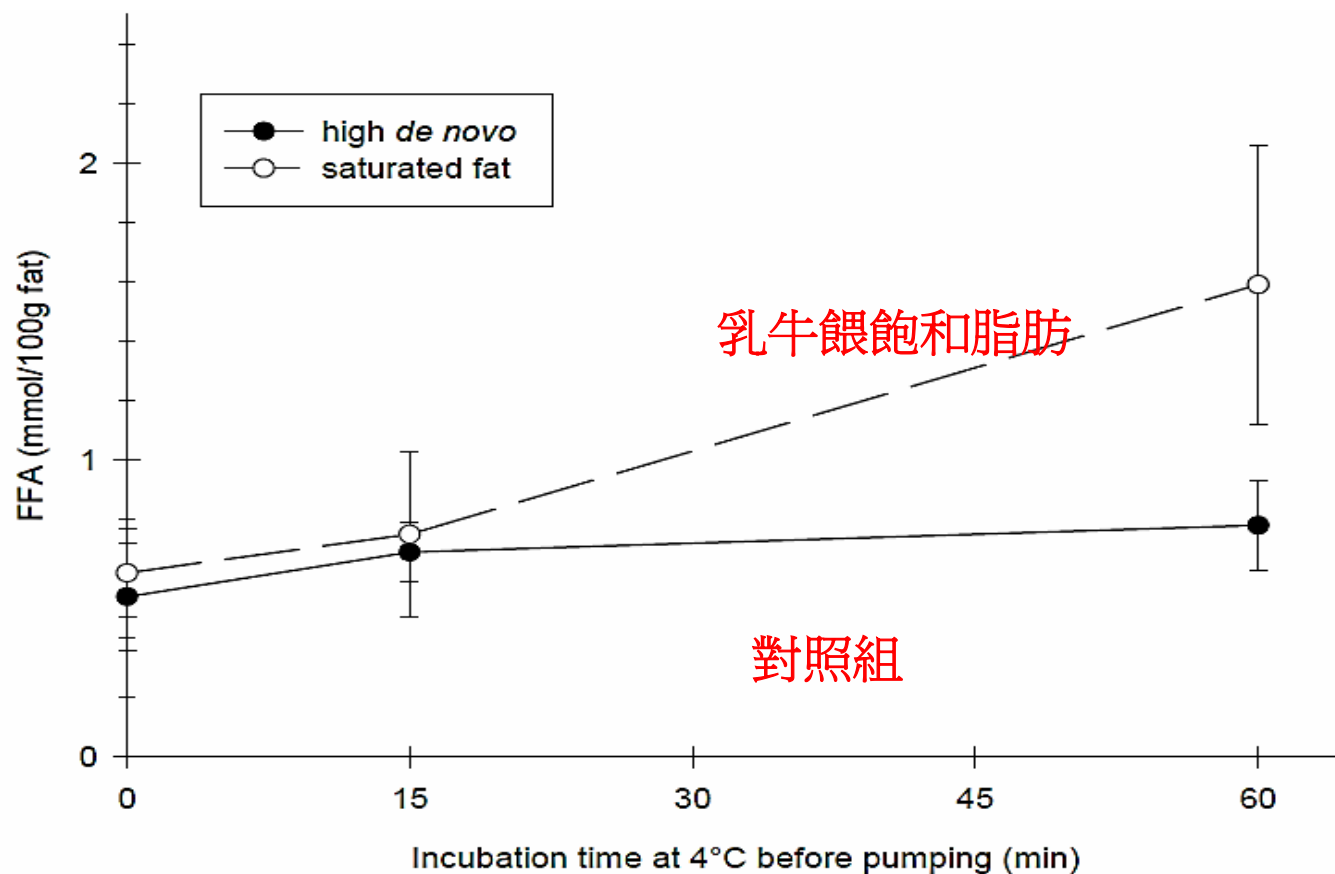


Figure 5. The effect of incubation time before pumping on the level of FFA in raw milk after pumping. The milk was from cows fed the saturated fat diet and the high *de novo* diet, respectively.

(Wiking, 2005; Doctoral thesis, Swedish University of Agricultural Sciences)

影響因素(7)-泌乳期天數

- 泌乳後期的乳脂率上升、脂肪球較小，提高脂肪被水解機會 (**Int. J. Agric. Sci. & Vet. Med. 2013, Vol. 1, No. 1**)。

影響因素(8)-精料比例

Table 2. Feed intake and yield for cows fed fish meal (FM) or pea meal (PM) diets

Item	40%精C (high concentrate level)				10%精C (low concentrate level)							
	魚粉	FM	豆粉	PM	SEM	P	魚粉	FM	豆粉	PM	SEM	P
Protein feed, kg DM		0.676		2.898				0.397		1.685		
Cereals, kg DM		3.735		1.446				2.225		0.849		
N in concentrates, kg		0.143		0.142				0.084		0.082		
NEL concentrates, MJ		35.00		34.87				20.80		20.34		
Silage, kg DM		13.19		13.03	0.788	0.89		13.81		13.65	0.564	0.85
BW change, g/d		0.018		-0.151	0.0872	0.19		-0.114		-0.060	0.0678	0.58
BCS ¹ change, points/100d		0.28		0.00	0.154	0.23		0.06		0.28	0.080	0.08
NH ₃ -N rumen fluid, mM		2.84		3.61	0.276	0.07		2.68		3.41	0.219	0.04
Milk yield, kg		23.2		21.7	0.44	0.03		20.1		18.9	0.37	0.04
Milk yield, kg ECM		23.0		22.5	0.46	0.46		20.0		18.9	0.45	0.12
Milk fat, g/kg		40.0		43.0	0.65	0.006		41.2		41.5	0.76	0.75
Milk protein, g/kg		32.3		32.2	0.41	0.80		30.7		31.1	0.28	0.33
Milk urea IR, mM		5.41		5.58	0.05	0.03		4.90		5.12	0.08	0.06
Milk FFA, meq/L		0.72		0.86	0.023	0.001		0.81		0.92	0.061	0.23
Milk flavour and odour ²		4.25		4.01	0.127	0.20		4.02		3.85	0.147	0.44

¹ five point scale with 0.25 point intervals, where 1 = emaciated and 5 = very fat animals

² five point scale, where 1 = poor quality milk and 5 = high quality milk

影響因素(9)-禁食

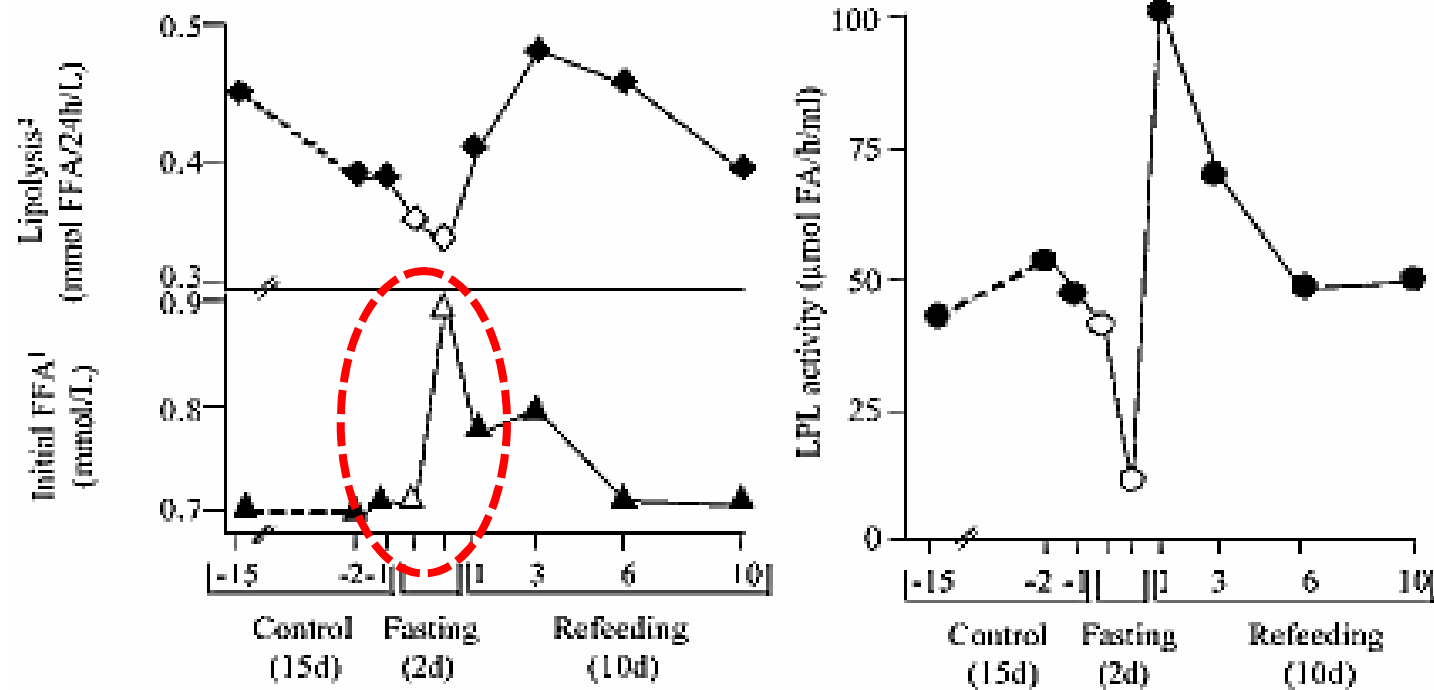


Figure 14. Effects of fasting and refeeding on Alpine goat milk lipolysis and lipoprotein lipase (LPL) activity (from Chilliard et al., 1981). ¹Level of free fatty acids (FFA) in fresh milk. ²Increase in milk FFA during 24-h storage at 4°C.

泌乳山羊2天禁食，增加乳中游離脂肪酸

(Chilliard et al., 2003; J. Dairy Sci. 86:1751–1770)

結語

- 游離脂肪酸提高會增加牛乳酸敗機會。
- 游離脂肪酸提高的非牛隻因素：擠乳系統生乳傳送管線壓力過高、過度攪拌、擠乳頻率大於一天兩次、生乳儲存時間延長、生乳儲存溫度升高。
- 游離脂肪酸提高的牛隻因素：餵飼飽和脂肪、精料比例低、泌乳天數增加、禁食(酮病)

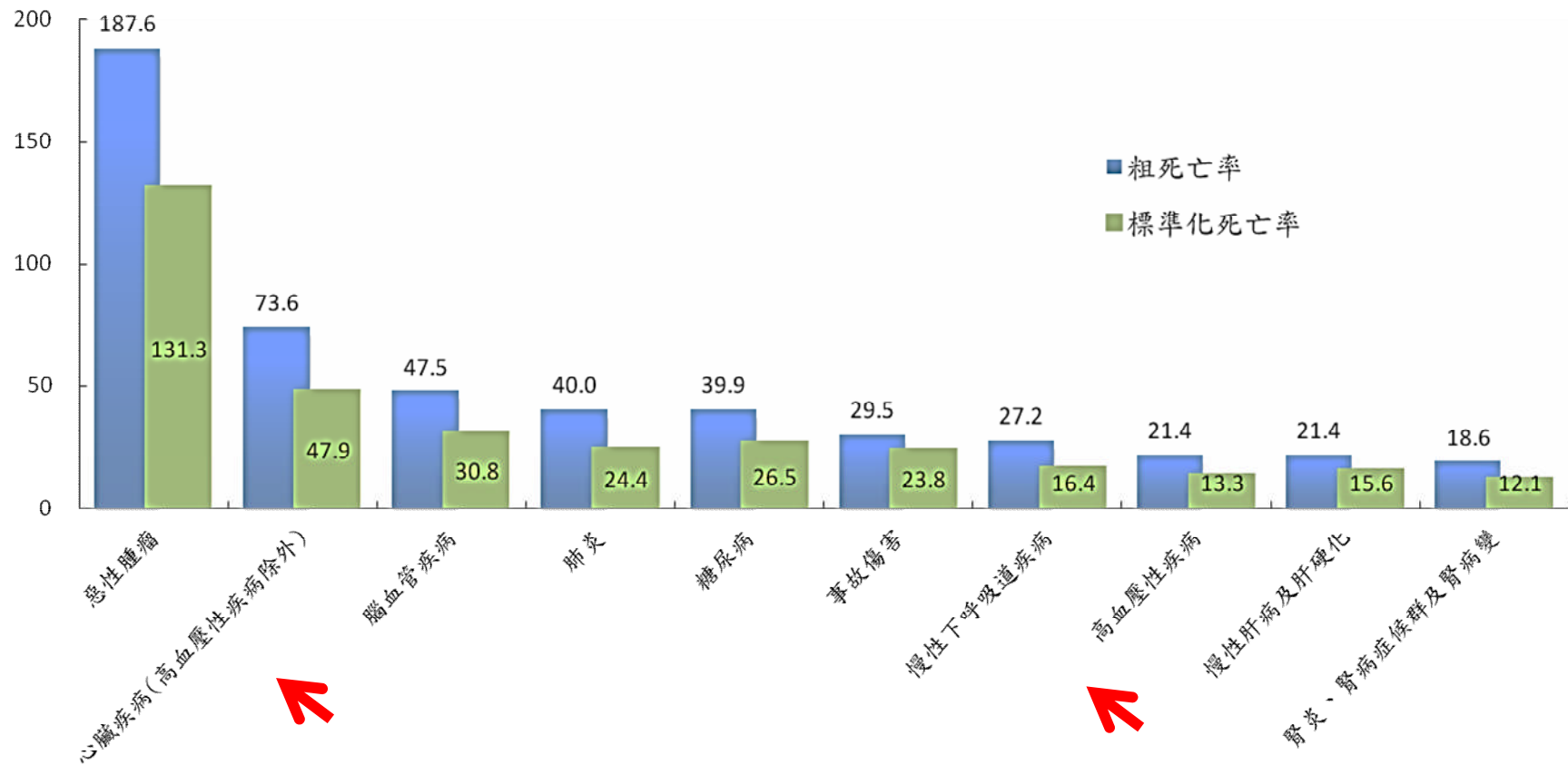
二、牛乳脂肪酸數據之應用

爲什麼要測牛乳脂肪酸組成？

- 消費者關心**肥胖問題、心血管問題**

圖3. 101年主要死因死亡率

每十萬人口死亡率



附註：標準化死亡率係以W.H.O.2000年世界標準人口數為基準。

牛乳每個三酸甘油脂含26-54碳

Table 2.4. Predominant distribution (mole percent) of fatty acids in milk fat triacylglycerols^a

Fatty acid	TAG position		
	sn-1	sn-2	sn-3
C _{4:0}	1.6	0.3	98.1
C _{6:0}	3.1	3.9	93.0
C _{8:0}	10.3	55.2	34.5
C _{10:0}	15.2	56.6	28.2
C _{12:0}	23.7	62.9	13.4
C _{14:0}	27.3	65.6	7.1
C _{16:0}	44.1	45.4	10.5
C _{18:0}	54.0	16.2	29.8
C _{18:1}	37.3	21.2	41.5

Advanced Dairy Chemistry, Volume 2: Lipids, 3rd edition.

Edited by P.F. Fox and P.L.H. McSweeney, Springer, New York, 2006.

甘油(C₃H₈O₃)MW=90 g, C₂₆ MW=466, C₅₄ MW=714→三酸甘油脂分子量502-750

牛乳脂肪酸組成

Fatty acids (g 100g ⁻¹)	Goat	Sheep	Cow
C4:0; butyric 短鏈脂肪	2.03 ¹	2.57 ²	2.87 ³
C6:0; caproic	2.78 ¹	1.87 ²	2.01 ³
C8:0; caprylic 酸鏈脂肪	2.92 ¹	1.87 ²	1.39 ³
C10:0; capric	9.59 ¹	6.63 ²	3.03 ³
C12:0; lauric 酸鏈脂肪	4.52 ¹	3.99 ²	3.64 ³
C14:0; myristic	9.83 ¹	10.17 ²	10.92 ³
C16:0; palmitic 酸	24.64 ¹	25.1 ²	28.7 ³
C18:0; stearic	8.87 ¹	8.85 ²	11.23 ³
18:1 <i>cis</i> -9; oleic	18.65 ¹	20.18 ²	22.36 ³
18:2 <i>cis</i> -9, <i>cis</i> -12; linoleic	2.25 ¹	2.32 ²	2.57 ³
18:2 <i>cis</i> -9, <i>trans</i> -11; CLA	0.45 ¹	0.76 ²	0.57 ³
18:3 <i>cis</i> -9, <i>cis</i> -12, <i>cis</i> -15; α -linolenic	0.77 ¹	0.92 ²	0.5 ³
total n-6	1.78 ⁴	2.97 ⁵	2.83 ⁶
total n-3	0.44 ⁴	1.31 ⁵	0.56 ⁶
SFA	68.79 ⁴	64.23 ⁵	68.72 ⁶
MUFA	24.48 ⁴	29.75 ⁵	27.40 ⁶
PUFA	3.70 ⁴	4.82 ⁵	4.05 ⁶
n-6/n-3	5.00 ⁴	2.31 ⁵	6.01 ⁶
AI 動脈粥樣硬化指數	2.88 ⁴	2.21 ⁵	2.55 ⁶
TI 血栓形成指數	3.17 ⁴	2.49 ⁵	3.22 ⁶
Total fat (g 100g ⁻¹)	4.27 ¹	6.09 ²	3.76 ³

WHO建議低於4

SFA - saturated fatty acids; MUFA - monounsaturated fatty acids; PUFA - polyunsaturated fatty acids; AI - atherogenic index; TI - thrombogenic index.

Calculated as (39): AI = (C12:0 + (4*C14:0) + C16:0)/(MUFA + (n-6) + (n-3)); TI=(C14:0 + C 16:0 + C18:0)/(0.5*MUFA + (0.5*n-6) + (3*n-3) + (n-3/n-6)). *Bull Vet Inst Pulawy 57, 135-139, 2013*

Table 2 Fatty acid composition of colostrum, transitional and mature milk (% wt/wt)

Fatty acids	Colostrum (n = 40) 1-6天		Transitional (n = 40) 7-15天		Mature (n = 40) >15天	
	Mean \pm s.d.	Range	Mean \pm s.d.	Range	Mean \pm s.d.	Range
C8:0	0.07 ^{a,b} \pm 0.04	0.00 – 0.21	0.19 \pm 0.07	0.06 – 0.35	0.21 \pm 0.06	0.11 – 0.36
C10:0	0.66 ^{a,b} \pm 0.37	0.15 – 1.87	1.66 \pm 0.57	0.55 – 3.10	1.63 \pm 0.47	0.85 – 3.08
C12:0	3.49 ^{a,b} \pm 1.77	1.40 – 8.76	6.97 \pm 2.21	3.00 – 11.31	6.28 \pm 1.33	4.05 – 9.35
C14:0	4.75 ^{a,b} \pm 1.65	2.46 – 8.93	6.94 \pm 1.88	4.03 – 11.63	6.00 \pm 1.44	3.60 – 9.13
C14:1 n-5	0.14 \pm 0.07	0.00 – 0.35	0.16 \pm 0.08	0.06 – 0.44	0.20 \pm 0.10	0.00 – 0.53
C15:0	0.23 \pm 0.05	0.16 – 0.39	0.25 \pm 0.17	0.09 – 1.11	0.23 \pm 0.07	0.11 – 0.48
C15:1	0.03 \pm 0.03	0.00 – 0.12	0.04 \pm 0.03	0.00 – 0.10	0.04 \pm 0.03	0.00 – 0.12
C16:0	21.17 ^{a,b} \pm 1.60	17.68 – 23.94	19.35 \pm 2.03	15.64 – 23.33	19.48 \pm 2.06	15.43 – 24.46
C16:1 n-9	0.62 ^{a,b} \pm 0.32	0.42 – 2.17	0.43 \pm 0.08	0.27 – 0.61	0.42 \pm 0.07	0.29 – 0.58
C16:1 n-7	1.36 ^b \pm 0.46	0.00 – 2.46	1.52 \pm 0.48	0.92 – 2.90	1.78 \pm 0.52	1.10 – 2.81
C17:0	0.35 ^{a,b} \pm 0.04	0.28 – 0.44	0.31 \pm 0.07	0.18 – 0.43	0.30 \pm 0.05	0.19 – 0.44
C17:1	0.19 \pm 0.03	0.13 – 0.26	0.18 \pm 0.04	0.11 – 0.28	0.19 \pm 0.05	0.10 – 0.34
C18:0	6.29 \pm 0.80	4.66 – 8.20	6.20 \pm 0.85	4.27 – 7.49	6.25 \pm 0.99	4.60 – 8.13
C18:1 n-9	38.83 ^{a,b} \pm 3.76	28.54 – 45.88	35.48 \pm 2.95	29.34 – 39.77	36.35 \pm 3.46	28.30 – 43.83
C18:2 n-6	16.10 \pm 2.73	11.19 – 22.80	15.74 \pm 3.73	8.80 – 24.10	16.59 \pm 4.10	10.61 – 25.30
C18:3 n-6	0.06 ^b \pm 0.06	0.00 – 0.18	0.07 ^c \pm 0.04	0.00 – 0.18	0.13 \pm 0.07	0.00 – 0.27
C20:0	0.19 \pm 0.06	0.00 – 0.31	0.19 \pm 0.04	0.07 – 0.29	0.20 \pm 0.05	0.13 – 0.35
C18:3 n-3	0.41 ^{a,b} \pm 0.07	0.23 – 0.56	0.58 \pm 0.13	0.31 – 0.79	0.75 \pm 0.32	0.41 – 1.68
C20:1 n-9	0.94 ^{a,b} \pm 0.19	0.64 – 1.50	0.68 \pm 0.18	0.36 – 1.19	0.60 \pm 0.13	0.34 – 0.82
C20:2 n-6	0.86 ^{a,b} \pm 0.15	0.54 – 1.19	0.56 ^c \pm 0.15	0.34 – 0.94	0.40 \pm 0.06	0.28 – 0.55
C20:3 n-6	0.65 ^{a,b} \pm 0.22	0.38 – 1.57	0.49 \pm 0.13	0.26 – 0.80	0.48 \pm 0.14	0.25 – 0.73
C22:0	0.08 \pm 0.11	0.00 – 0.67	0.04 \pm 0.04	0.00 – 0.10	0.05 \pm 0.03	0.00 – 0.09
C20:4 n-6	0.74 ^{a,b} \pm 0.14	0.46 – 1.12	0.67 ^c \pm 0.14	0.50 – 0.97	0.53 \pm 0.12	0.23 – 0.75
C22:1 n-9	0.18 ^{a,b} \pm 0.11	0.00 – 0.66	0.10 ^c \pm 0.06	0.00 – 0.27	0.06 \pm 0.03	0.00 – 0.10
C23:0	0.02 \pm 0.03	0.00 – 0.11	0.04 \pm 0.03	0.00 – 0.11	0.05 \pm 0.03	0.00 – 0.08
C20:5 n-3	0.19 ^{a,b} \pm 0.03	0.13 – 0.24	0.11 \pm 0.05	0.05 – 0.23	0.10 \pm 0.05	0.00 – 0.24
C24:0	0.09 \pm 0.05	0.00 – 0.22	0.05 \pm 0.06	0.00 – 0.20	0.03 \pm 0.02	0.00 – 0.07
C22:4 n-6	0.44 ^{a,b} \pm 0.16	0.24 – 0.80	0.23 ^c \pm 0.17	0.10 – 0.88	0.15 \pm 0.04	0.09 – 0.24
C22:4 n-3	0.08 ^b \pm 0.03	0.00 – 0.14	0.07 ^c \pm 0.03	0.00 – 0.12	0.04 \pm 0.03	0.00 – 0.08
C22:5 n-6	0.04 ^b \pm 0.04	0.00 – 0.13	0.03 \pm 0.04	0.00 – 0.11	0.01 \pm 0.05	0.00 – 0.22
C22:5 n-3	0.20 ^b \pm 0.06	0.09 – 0.36	0.16 ^c \pm 0.06	0.08 – 0.33	0.12 \pm 0.02	0.08 – 0.16
C22:6 n-3	0.56 ^b \pm 0.16	0.39 – 0.92	0.50 ^c \pm 0.15	0.29 – 0.79	0.36 \pm 0.12	0.15 – 0.56

Table 2 Fatty acid composition of colostrum, transitional and mature milk (% wt/wt)

Fatty acids	Colostrum (n = 40) 1-6天		Transitional (n = 40) 7-15天		Mature (n = 40) >15天	
	Mean ± s.d.	Range	Mean ± s.d.	Range	Mean ± s.d.	Range
SFA	37.37 ^{a,b} ± 3.72	30.06–46.24	42.15 ± 3.44	35.86–52.40	40.66 ± 3.87	34.18–47.48
MUFA	42.29 ^{a,b} ± 4.02	31.14–49.71	38.59 ± 3.24	32.05–43.31	39.63 ± 3.57	32.08–47.34
PUFA	20.34 ± 2.73	16.05–27.00	19.26 ± 3.73	11.63–27.98	19.71 ± 4.38	13.26–29.15
PUFA n-3	1.44 ± 0.19	0.93–1.74	1.42 ± 0.37	0.86–2.44	1.38 ± 0.45	0.81–3.06
PUFA n-6	18.89 ± 2.68	14.81–25.77	17.79 ± 3.70	10.61–26.00	18.33 ± 4.22	12.10–27.77
LC-PUFA n-3	1.03 ^b ± 0.19	0.58–1.44	0.84 ^c ± 0.29	0.53–1.60	0.63 ± 0.18	0.34–0.89
LC-PUFA n-6	2.73 ^{a,b} ± 0.38	1.98–3.43	1.98 ^c ± 0.47	1.39–3.50	1.61 ± 0.26	1.17–2.16
n-6/n-3	14.70 ± 2.68	10.26–22.85	13.08 ± 4.34	6.63–22.20	13.99 ± 4.02	7.31–21.13
LA/LnA	42.02 ^{a,b} ± 7.84	26.14–59.70	30.56 ± 8.62	18.19–50.96	24.84 ± 6.57	14.41–39.49
AA/DHA	1.48 ± 0.36	1.07–2.39	1.41 ± 0.44	0.58–2.25	1.61 ± 0.56	0.61–2.55

^aDenotes significant differences ($P < 0.05$) between colostrum and mature milk groups.

^bDenotes significant differences ($P < 0.05$) between colostrum and transitional milk groups.

^cDenotes significant differences ($P < 0.05$) between transitional and mature milk groups.

ND, not detectable.

LA/LnA, linoleic acid/linolenic acid; AA/DHA, arachidonic acid/docosahexaenoic acid.

n-6/n-3: WHO建議低於4

European Journal of Clinical Nutrition (2002) 56, 1242–1254

不同品種牛乳脂肪酸組成

Table 1. Daily yield and composition of milk and fatty acid (FA) composition of milk fat obtained from different breeds of dairy cattle²

	Breed					SEM
	H 荷蘭牛	BSH	BS 瑞士黃牛	BSJ	J 娟珊牛	
Milk yield (kg)	30.3a	25.4b	23.7b	20.5c	17.6d**	4.06
Composition (%)						
Fat	3.74a	4.22b	4.20b	4.72c	4.81c**	0.318
Protein	3.16a	3.48b	3.64c	3.84d	3.95d**	0.097
FA composition ³ (wt%)						
C4:0	4.08	4.04	4.02	3.93	3.88	0.137
C6:0	2.71a	2.64c	2.77ab	2.76ab	2.80b*	0.050
C8:0	1.59a	1.56a	1.67b	1.68b	1.71b**	0.044
C10:0	3.68a	3.76ab	3.83b	4.05c	4.18c**	0.112
C12:0	4.26a	4.57b	4.53b	4.85c	4.98c**	0.174
C14:0	13.56	13.75	13.85	13.50	13.88	0.324
C16:0	35.33	36.16	34.73	35.19	34.89	0.682
C16:1 trans	0.44ab	0.48a	0.44ab	0.39b	0.41b	0.040
C16:1 cis	1.99	1.94	1.96	1.90	1.80	0.090
C18:0	8.93a	8.22b	8.32b	8.58ab	9.52c**	0.444
C18:1 trans 9	0.21	0.24	0.19	0.20	0.23	0.039
C18:1 trans 11	1.51	1.44	1.51	1.50	1.54	0.106
C18:1 cis 9+10	17.88ab	17.37b	18.58a	17.44b	16.18c**	0.689
C18:2	2.53	2.41	2.41	2.50	2.57	0.152
C18:3	1.29ab	1.42ab	1.20b	1.53a	1.49ab*	0.193
C18:1/C18:0	2.06a	2.14a	2.26b	2.06a	1.72c**	0.087
SCFA	8.38	8.24	8.46	8.38	8.38	0.191
MCFA	21.50a	22.08ab	22.21ab	22.40bc	23.04c*	0.555
LCFA	32.35	31.10	32.21	31.74	31.48	1.093
C6 to C14	25.80a	26.28ab	26.65b	26.85bc	27.54c*	0.615
TUNS 不飽和脂肪酸	25.86a ←	25.30a	26.30a ←	25.45a	24.18b** ←	0.812

² Values are least-squares means.

³ SCFA = short chain FA (C4:0 + C6:0 + C8:0); MCFA = medium chain FA (C10:0 + C12:0 + C14:0); LCFA = long chain FA (C18:0 + C18:1 trans 11 + C18:1 cis 9 + 10 + C18:2 + C18:3); C6 to C14 = (C6:0 + C8:0 + C10:0 + C12:0 + C14:0); TUNS = total unsaturated FA (C16:1 trans + C16:1 cis + C18:1 cis 9 + 10 + C18:1 trans 9 + C18:1 trans 11 + C18:2 + C18:3).

a-d Values followed by different letters within each row are significantly different (*P < 0.05; **P < 0.01).

影響牛乳脂肪酸組成因素 (2)

- 乳腺合成(C4-C16，飽和)或血液傳送

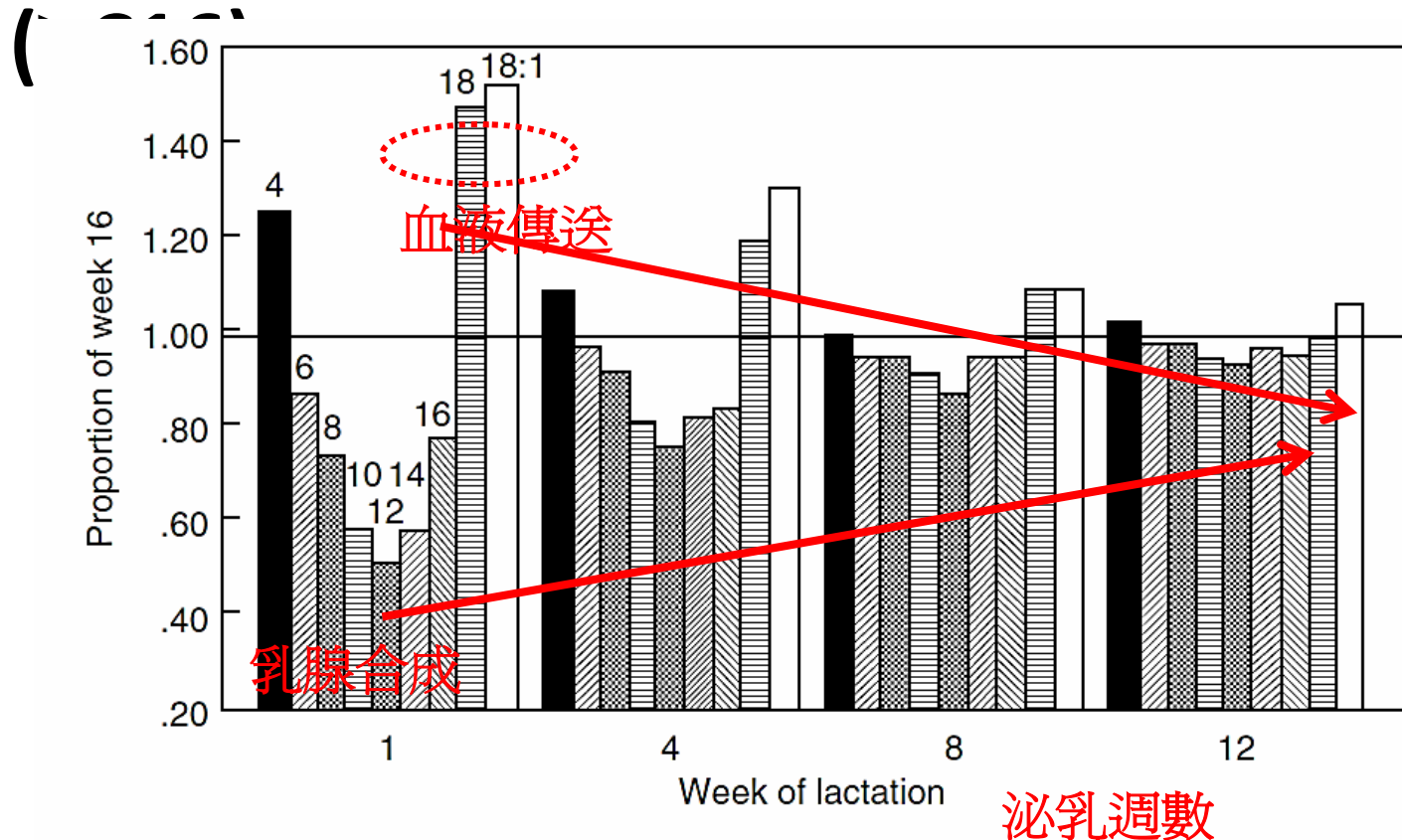
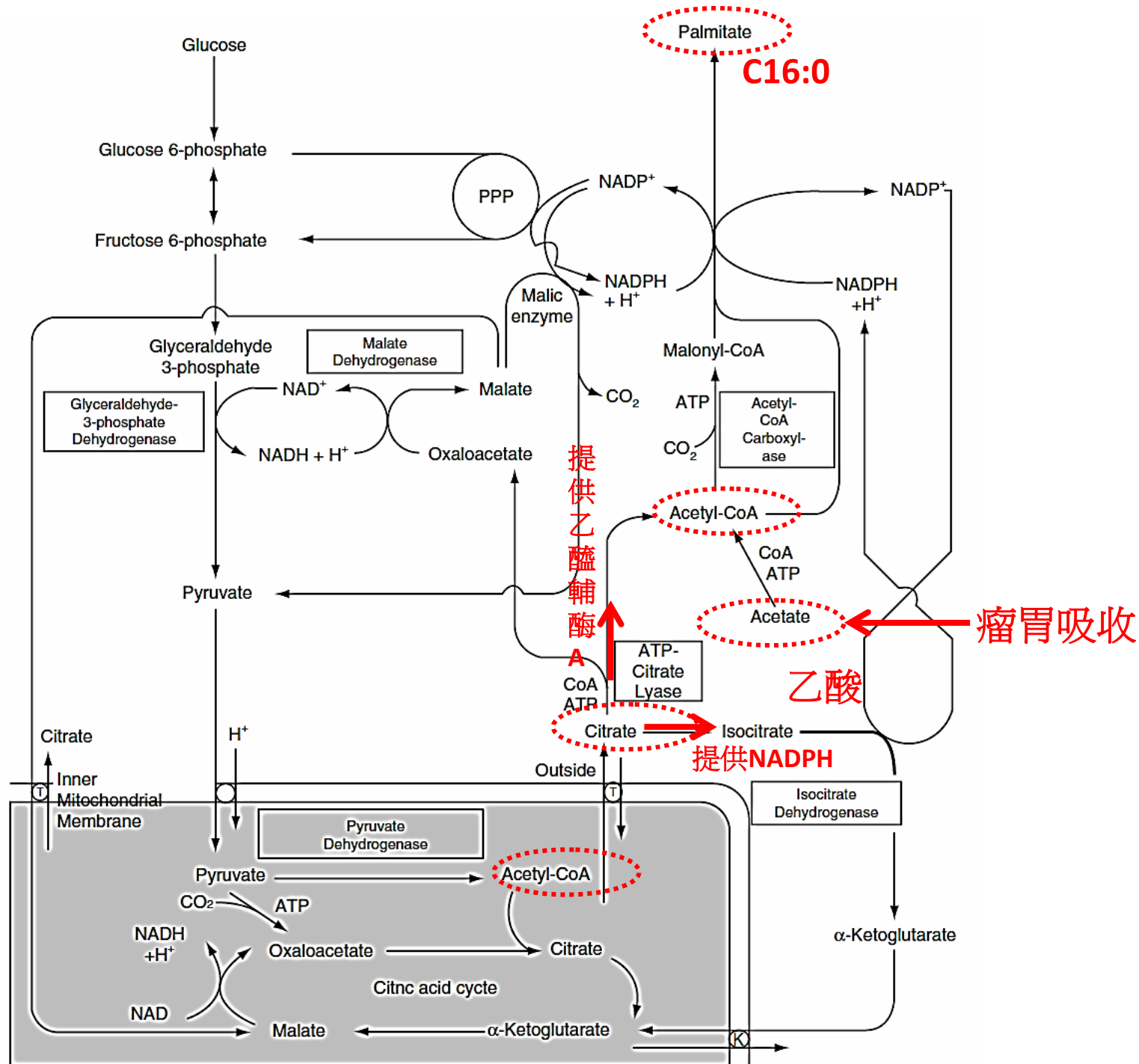


Figure 2.6. Proportions of individual fatty acids in milk fat at 1, 4, 8 and 12 weeks of lactation relative to their proportions at 16 weeks (from Palmquist *et al.*, 1993. *J. Dairy Sci.* 76, 1753–1771).



Advanced Dairy Chemistry, Volume 2: Lipids, 3rd edition.
 Edited by P.F. Fox and P.L.H. McSweeney, Springer, New York, 2006.

檸檬酸與牛乳偶數碳脂肪酸正相關

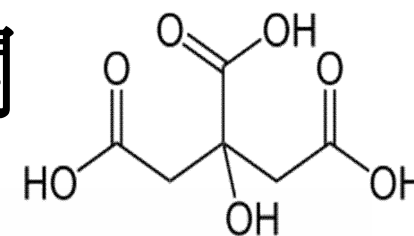


Table 5. Relationship between CA yields (ml) and the fatty acid yields (ml)

Even SFA	Summer 夏季			Winter 冬季		
	CV ¹	r ²	P	CV	r	P
c4	23	0.4	***	20	0.44	***
c6	25	0.38	***	21	0.37	***
c8	27	0.33	***	23	0.32	***
c10	29	0.29	***	25	0.26	***
c12	32	0.34	***	28	0.28	***
c14	24	0.43	***	21	0.39	***
c16	27	0.33	***	21	0.29	***
<u>Odd SFA</u>						
c5	116	0.08	***	63	0.02	***
c7	115	-0.038	NS	69	-0.06	NS
c9	91	-0.024	NS	58 ^g	-0.043	NS
c11	67	0.01	NS	57	-0.06	NS
c13	46	0.06	NS	23	-0.01	NS
c15	26	0.194	***	27	0.095	***
c17	20	0.37	***	21	0.32	***

芻料比例 (3)

Table 3. Effect of diet on milk FA (g/100 g of FA) from dairy cows fed a low (LO), medium (MD), or high (HI) proportion of grass silage (data from 2 yr)

FA	Diet ¹			SEM	Significance ²	
	LO 低 (n = 17)	MD 中 (n = 20)	HI 高 (n = 13)		Linear	Quadratic
C4:0	2.61	2.24	2.68	0.38	NS	NS
C6:0	2.15	1.98	2.11	0.13	NS	NS
C8:0	1.49	1.41	1.38	0.05	NS	NS
C10:0	3.68	3.33	3.26	0.13	*	NS
C12:0	3.93	3.75	3.63	0.15	NS	NS
<i>cis</i> -9 C12:1	0.18	0.17	0.17	0.01	NS	NS
C14:0	12.6	12.4	12.2	0.29	NS	NS
<i>iso</i> C14:0	0.07	0.07	0.08	0.01	NS	NS
<i>cis</i> -9 C14:1	1.00	1.04	0.97	0.07	NS	NS
C15:0	0.94	1.00	1.06	0.03	*	NS
<i>iso</i> C15:0	0.18	0.19	0.21	0.01	*	NS
<i>anteiso</i> C15:0	0.39	0.40	0.42	0.02	NS	NS
C16:0	25.9	29.1	29.8	0.83	***	*
<i>iso</i> C16:0	0.26	0.29	0.26	0.03	NS	NS
<i>cis</i> -9 C16:1 ³	1.04	1.31	1.72	0.08	***	NS
C17:0	0.53	0.57	0.67	0.02	***	NS
<i>iso</i> C17:0	0.33	0.29	0.47	0.07	NS	NS
<i>cis</i> -9 C17:1	0.00	0.01	0.02	0.008	NS	NS
C18:0	12.0	11.1	9.8	0.40	***	NS
Σ <i>cis</i> C18:1	22.4	21.3	21.0	0.61	NS	NS
Σ <i>trans</i> C18:1	2.73	2.44	2.43	0.24	NS	NS
<i>cis</i> -9, <i>trans</i> -11 C18:2 CLA ⁴	0.67	0.80	0.90	0.08	*	NS

乳腺合成

穀類提供

瘤胃微生物轉換

芻料比例 (3)

Table 3. Effect of diet on milk FA (g/100 g of FA) from dairy cows fed a low (LO), medium (MD), or high (HI) proportion of grass silage (data from 2 yr)

FA	Diet ¹			SEM	Significance ²	
	LO (n = 17) 低	MD (n = 20) 中	HI (n = 13) 高		Linear	Quadratic
Total SFA 總飽和脂肪酸	67.3	68.5	68.4	0.97	NS	NS
Total MUFA 總單元不飽和脂肪酸	27.5	26.3	26.5	0.77	NS	NS
Total PUFA 總多元不飽和脂肪酸	3.49	3.58	3.42	0.30	NS	NS
MCSEFA ⁵	20.2	19.5	19.1	0.50	NS	NS
Total OBCFA ⁶	2.77	2.85	3.25	0.10	**	NS
C18:2n-6/C18:3n-3	2.9	2.0	1.6	0.19	***	*

¹LO = 50%, MD = 70%, and HI = 85% grass silage in the diet (DM basis).

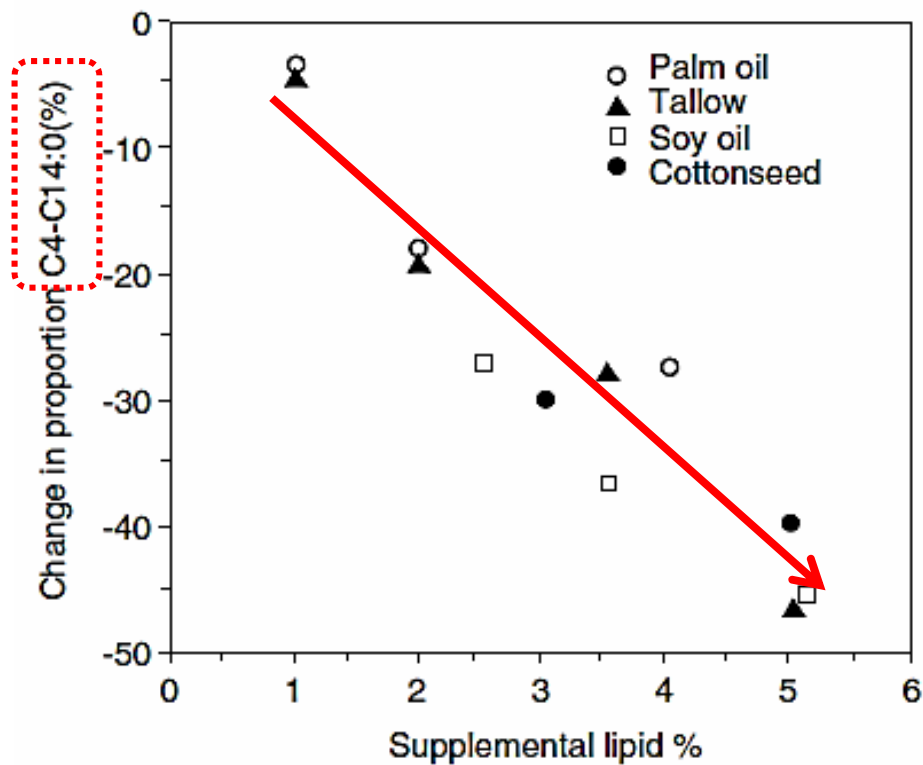
J. Dairy Sci. 96 :390–397, 2013

脂肪添加 (4)

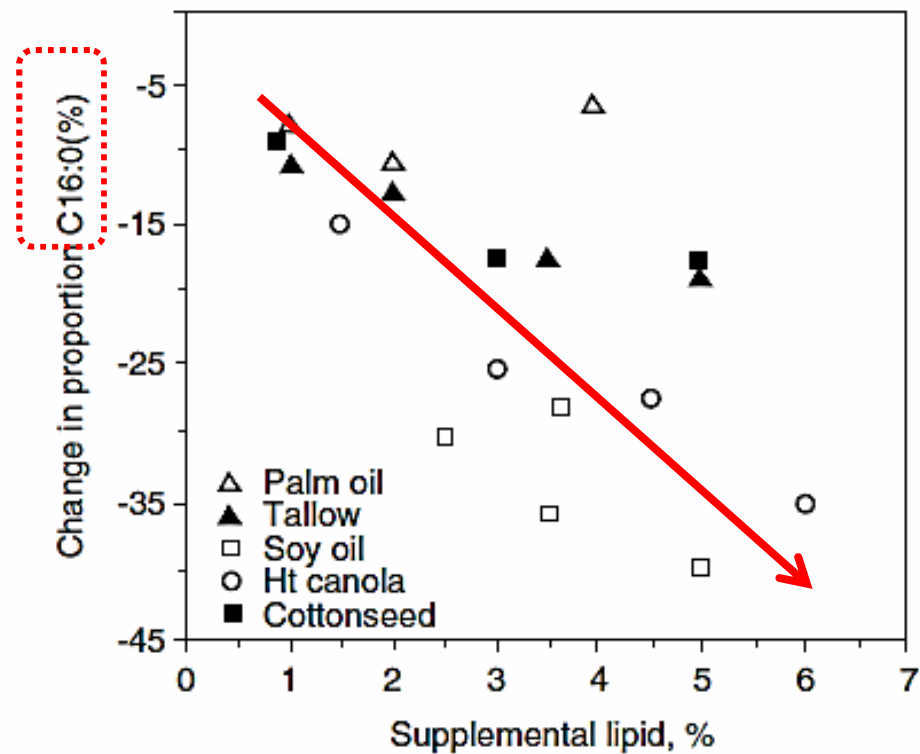
	Calcium salts						Whole roasted soybeans	Tallow	Fish oil
	None	Palm oil	Palm oil	Canola	Soy	Linseed			
% of feed DM	–	3.0	1.0	5.0	4.9	4.3	4.6	5.4	2.0
Reference	a	a	b	c	c	c	d	d	e
Fatty acid	weight % of reported fatty acids								
C _{4:0}	3.25	3.15	3.43	4.52	4.65	4.92	3.65	2.65	3.88
C _{6:0}	2.28	1.92	2.23	2.33	2.39	2.89	2.34	1.59	2.66
C _{8:0}	1.57	1.24	1.27	1.16	1.14	1.52	1.31	0.83	1.30
C _{10:0}	3.36	2.31	2.88	2.59	2.34	3.09	2.77	1.75	2.83
C _{12:0}	4.11	2.92	3.19	2.53	2.21	2.71	3.03	2.23	3.16
C _{14:0}	13.13	10.35	10.09	9.39	8.10	9.20	9.75	10.70	11.40
C _{14:1c-9}	0.95	0.74	–	1.10	0.74	0.71	1.05	1.73	0.77
C _{15:0}	1.10	0.82	–	1.06	0.84	0.96	–	–	0.98
C _{16:0}	32.58	34.75	30.25	19.26	19.25	19.09	25.44	31.68	27.56
C _{16:1c-9}	1.83	2.18	1.59	1.20	0.90	0.84	1.33	3.08	1.40
C _{18:0}	10.74	10.50	10.74	15.04	14.76	14.99	12.79	9.40	8.11
C _{18:1c-9}	20.23	24.60	23.80	26.95	25.99	22.92	21.88	23.73	15.08
C _{18:1t-11}	–	–	–	8.42	12.59	10.18	3.95	4.96	2.34
C _{18:2}	2.70	2.76	4.09	2.32	2.45	3.30	5.27	2.36	2.20
C _{18:3}	1.28	1.13	0.47	0.20	0.19	0.31	1.00	0.43	0.85
C _{18:2c-9, t-11}	–	–	0.49	–	–	–	1.03	0.81	0.88
C _{18:2t-10, c-12}	–	–	0.03	–	–	–	–	–	0.04
C _{20:5} n-3 EPA	–	–	–	–	–	–	–	–	0.24 ←
C _{22:5} n-3	–	–	–	–	–	–	–	–	0.28
C _{22:6} n-3 DHA	–	–	–	–	–	–	–	–	0.26 ←

Edited by P.F. Fox and P.L.H. McSweeney, Springer, New York, 2006.
 Advanced Dairy Chemistry, Volume 2: Lipids, 3rd edition.

脂肪添加 (4)

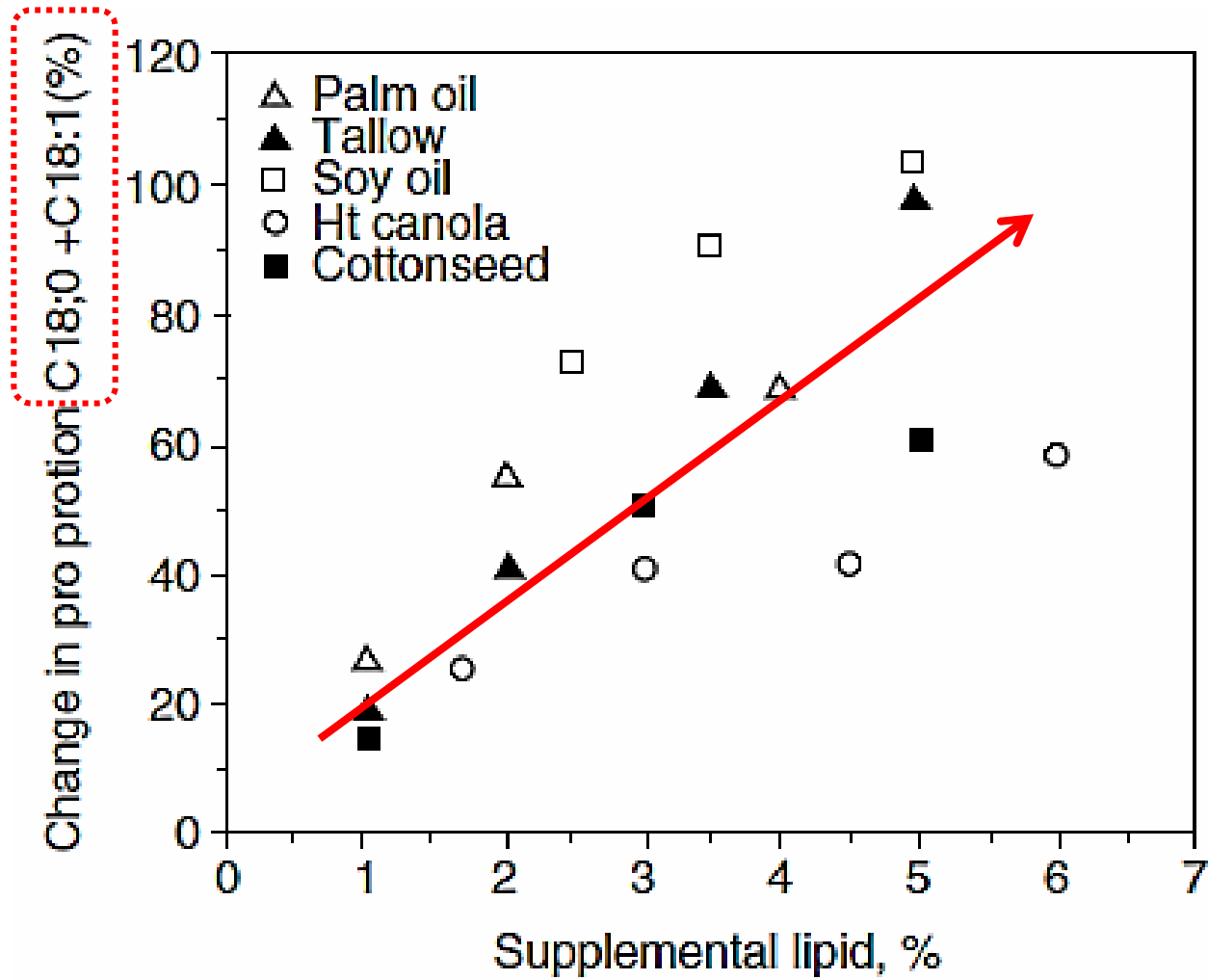


脂肪添加量



脂肪添加量

脂肪添加 (4)



脂肪添加量

魚油與葵花油組合比例

Table 2

Dry matter intake and production of cows fed combinations of sunflower/fish oil^a

Parameter	Proportion of fish oil in oil supplement				S.E.	P ^b
	0	0.33	0.67	1.00		
Dry matter intake (kg/day)	17.2	17.2	15.5	14.5	1.34	<0.03L
Milk yield (kg/day)	22.1	21.6	20.3	19.8	2.83	NS
Milk fat (g/kg milk)	20.6	22.8	26.2	26.4	3.03	<0.02L
Milk protein (g/kg milk)	29.8	29.2	28.8	29.5	1.35	<0.08Q
Milk fat (g/day)	430	495	532	501	73.8	NS
Milk protein (g/day)	650	620	585	546	73.8	NS

^a All cows were fed 30 g oil/kg of diet dry matter.

^b L = linear effect, Q = quadratic effect, and NS = P > 0.10.

Animal Feed Science and Technology
131 (2006) 358–369

Composition (mg/g fatty acids) of the fatty acids in sunflower and fish oils^a

Fatty acid	Sunflower oil	Fish oil
14:0	0.06 ^b	82.6
14:1	0	7.3
16:0	68.5	195.2
16:1	0.7	116.6
17:0	0.7	16.9
18:0	44.2	38.2
18:1 <i>trans</i>	0	20.1
18:1 <i>cis</i> -9	192.4	80.3
18:1 <i>cis</i> -11	8.0	31.7
18:2 _{n-6}	639.6	13.0
18:3 _{n-3}	15.1	14.5
20:0	3.3	–
20:1	2.1	27.2
20:2	–	2.1
20:4 _{n-6}	0	1.8
20:3 _{n-6}	–	1.9
20:5 _{n-3} EPA	–	120.4
22:5 _{n-3}	–	23.9
22:6 _{n-3} DHA	–	101.1
Other	24.9	93.5

^a Sunflower oil and Menhaden fish oil were both from Cereal By-Products, Mt. Prospect, IL, USA.

^b Values represent duplicate analyses of two individual samples.

Fatty acid concentrations (mg/g fatty acids) in milk fat with increasing fish oil in the diet

Fatty acid	Proportion of fish oil in oil supplement				S.E.	P
	0	0.33	0.67	1.00		
4:0	33.4	35.8	49.6	52.7	3.67	<0.001L
6:0	13.7	14.6	21.5	25.0	1.96	<0.001L
8:0	6.4	6.9	10.8	13.6	1.26	<0.001L
10:0	13.3	14.3	21.6	27.7	2.60	<0.001L
12:0	17.8	20.1	25.0	31.4	2.67	<0.01L
14:0	77.8	87.1	100	110	4.55	<0.001L
14:1	8.8	11.2	10.0	9.4	1.65	NS ^a
15:0	10.8	11.9	13.2	15.6	1.00	<0.001L
16:0	224	261	283	309	15.0	<0.01L
16:1	19.8	28.0	36.1	44.5	2.62	<0.001L
18:0	108	61.8	36.5	36.2	11.8	<0.001L
18:1 <i>t</i> 6-8	8.4	8.6	4.3	2.3	1.47	<0.01L
18:1 <i>t</i> 9	8.1	9.4	6.9	4.3	1.12	<0.02L
18:1 <i>t</i> 10	43.1	35.9	27.6	31.3	15.4	NS
18:1 <i>t</i> 11	72.4	114	136	79.8	21.3	<0.01Q
18:1 <i>t</i> 12	10.2	12.8	10.9	9.5	0.94	NS
18:1 <i>c</i> 9	224	148	85.8	76.8	32.6	<0.01L
18:1 <i>c</i> 11	8.1	10.3	12.6	20.6	2.46	<0.001L
18:2	34.8	27.2	20.4	22.9	2.38	<0.01L
18:3	8.4	9.3	8.3	8.8	1.13	NS
CLA <i>c</i> 9, <i>t</i> 11	40.2	60.9	58.4	34.3	8.02	<0.01Q
CLA <i>t</i> 10, <i>c</i> 12	1.1	1.0	1.0	1.2	0.23	NS
20:4 _n - 6	0.2	ND ^b	1.3	1.5	0.21	<0.001L
20:5 _n - 3	1.2	1.4	5.8	6.8	1.50	<0.01L
22:5 _n - 3	0.6	0.7	1.7	3.0	0.58	<0.01L
22:6 _n - 3	ND	ND	0.6	0.9	0.29	<0.05L

n6/n3= 3 n6/n3= 2

魚油阻擋飽和化作用

Table 1. Changes in Body Composition as a Result of 12 Weeks of CLA Feeding

	Δ Body Weight (kg)	Δ Body Fat Mass (kg)	Δ Lean Body Mass (kg)
Olive oil 9 g/d	+1.4 +/- 1.9	+1.47 +/- 2.43	-0.05 +/- 2.43
CLA 1.7 g/d	-0.4 +/- 2.6	-1.15 +/- 2.69	+0.87 +/- 1.57
CLA 3.4 g/d	-0.4 +/- 1.7	-1.73 +/- 1.90	+1.26 +/- 2.17
CLA 5.1 g/d	-0.1 +/- 0.9	-0.43 +/- 1.74	+0.54 +/- 1.44
CLA 6.8 g/d	-0.8 +/- 2.0	-1.30 +/- 1.46	+0.88 +/- 1.06

Values represent the mean changes and the standard deviation for the group
 Δ indicates change. Adapted from Blankson H, Stakkestad JA, Fagertun H, et al. Conjugated linoleic acid reduces body fat mass in overweight and obese humans. *J Nutr* 2000;130:2943-2948.

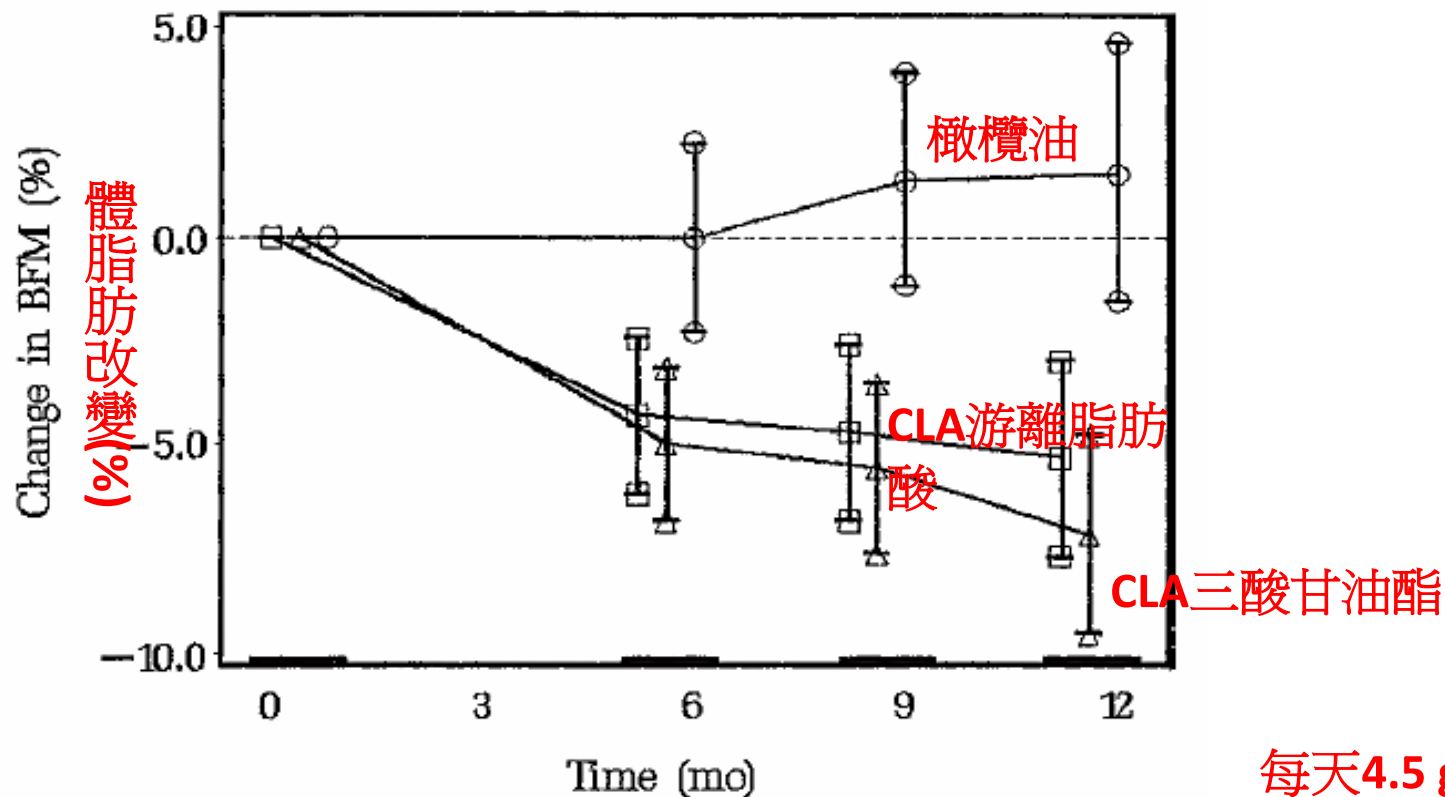


FIGURE 1. Mean (95% CI) percentage change in body fat mass (BFM) in subjects taking placebo (O), CLA-free fatty acids (FFA; □), or CLA-triacylglycerol (△) for 12 mo. All values were measured at the same points (ie, 0, 6, 9, and 12 mo) in all 3 groups. Intervals not including 0 are significant within the group. Between-group comparisons of changes from month 0 in DXA and weight variables were performed by using ANCOVA (treatment, center, and sex as factors; month 0 value, total energy intake, exercise, and drug × energy intake and drug × training score interactions as covariates). A significant time × treatment interaction was found ($P = 0.001$). Differences between both CLA groups and the placebo group were significant at 6, 9, and 12 mo ($P < 0.05$). There was no difference between the CLA-FFA and CLA-triacylglycerol groups ($P \geq 0.05$).

每天4.5 g
橄欖油
或CLA

全油籽添加 (5)

Table 2.1. Fatty acid composition (weight % of total fatty acids) of milk fat from cows fed a standard diet or supplemented with protected oilseeds

Fatty acid	Control ^a	Sunflower/soybean ^a	葵花籽/ 黄豆	Canola ^b 油菜籽
C ₄	3.2	2.8		3.2
C ₆	2.2	1.4		2.4
C ₈	1.1	0.8		1.9
C _{10:0}	3.6	1.7		3.2
C _{12:0}	3.9	1.7		3.6
C _{14:0}	11.4	5.9		9.5
C _{15:0}	2.1	0.9		—
C _{16:0}	25.9	15.2		19.9
C _{16:1}	2.7	0.5		3.3
C _{18:0}	10.9	14.0		9.2
C _{18:1}	28.6	37.6		29.2
C _{18:2} n6	3.0	16.6	n6/n3=18	4.9
C _{18:3} n3	1.0	0.9	3	2.6

^a Calculated from Barbano and Sherbon (1980). Formaldehyde-protected sunflower/soybean (70/30); 1250 g oil/day.

^b Ashes *et al.* (1992). Formaldehyde-protected canola; 520 g oil/day.

全油籽添加 (5)

TABLE 5. Fatty acid composition of milk fat for cows fed the control (C) diet or the diet containing supplemental fat (F) with or without niacin (N) supplementation.

Fatty acid ¹	Diet				SE	Main effect		
	C	C + N	F	F + N		F	N	F × N
	(g/100 g of fatty acids)					P		
4:0	6.22	6.31	6.61	6.44	0.18	0.11	0.84	0.43
6:0	4.30	4.39	3.85	3.75	0.11	<0.01	0.90	0.32
8:0	2.61	2.66	2.04	1.96	0.06	<0.01	0.76	0.21
10:0	5.34	5.37	3.77	3.63	0.09	<0.01	0.50	0.31
12:0	5.70	5.77	3.69	3.59	0.09	<0.01	0.87	0.28
14:0	11.63	11.44	9.43	9.39	0.15	<0.01	0.39	0.56
14:1	2.61	2.63	1.51	1.56	0.08	<0.01	0.63	0.81
15:0	1.81	1.87	0.98	0.96	0.08	<0.01	0.81	0.57
15:1	0.33	0.35	0.24	0.24	0.02	<0.01	0.64	0.55
16:0	18.00	17.95	15.27	14.90	0.35	<0.01	0.51	0.61
16:1	4.18	4.05	2.64	2.70	0.12	<0.01	0.75	0.40
17:0	0.92	0.98	0.59	0.57	0.04	<0.01	0.52	0.25
17:1	0.35	0.36	0.21	0.22	0.02	<0.01	0.79	0.89
18:0	10.06	10.04	13.42	13.58	0.23	<0.01	0.75	0.68
18:1	18.26	17.94	24.39	24.94	0.24	<0.01	0.60	0.04
18:2	3.61	3.51	5.81	6.50	0.19	<0.01	0.08	0.02
18:3	0.37	0.34	1.07	0.96	0.08	<0.01	0.33	0.66
SCFA ²	24.45	24.90	20.57	19.72	0.42	<0.01	0.60	0.08
MCFA ³	39.84	39.62	30.87	30.54	0.37	<0.01	0.41	0.86
LCFA ⁴	32.31	31.84	44.69	45.98	0.46	<0.01	0.25	0.02
Saturated	66.60	66.78	59.66	58.77	0.54	<0.01	0.47	0.27
Unsaturated	30.00	29.58	36.48	37.47	0.38	<0.01	0.35	0.05
Other	3.40	3.64	3.86	3.76	0.22	0.20	0.99	0.28

¹Number of carbons:number of double bonds.

²Short-chain fatty acids = C_{4:0} to C_{12:0}.

³Medium-chain fatty acids = C_{14:0} to C_{17:1}.

⁴Long-chain fatty acids = C_{18:0} to C_{18:3}.

擠出全脂黃豆 → ↑ 不飽和脂肪酸

1997 J Dairy Sci 80:1329-1338

結語

- 牛乳飽和脂肪酸含量高於母乳 (69 vs. 40%總脂肪酸)，但是 n-6/n-3 比例優於母乳 (6 vs. 14)。
- 泌乳牛飼糧添加植物油或全油籽可降低牛乳飽和脂肪酸含量 (45-59 vs. 69%)。
- WHO 建議 n-6/n-3 比例低於 4，可藉由添加魚油或葵花油/魚油來達成。
- 牛乳含共軛亞麻油酸 (CLA) 對人體健康有益。
- 乳腺自行合成脂肪酸 (C4-C16) 越多，越有乳香。