Detailed Milk Fatty Acid Profiling on Origin and Chain Length

分析乳脂肪酸來源及長中短脂肪酸種類之新科技

乳質成分檢測新科技導入乳業研商會議
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大綱

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- 分析乳脂肪酸來源及長中短脂肪酸種類之新科技
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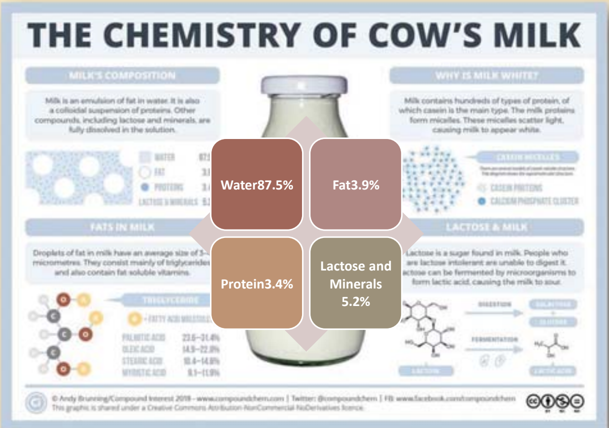
前言



生乳驗收無脂固形物率及乳脂率綜合計價表

（單位：新臺幣）

無脂固形物率（SNF %）：8.00-8.16 | 8.17-8.48 | 8.49-8.80 | 8.81-9.17 | 9.18以上

SNF %	8.49-8.80	8.49-8.80
FAT%/Period	Winter	Summer
2.8	16.65	23.57
3.0	20.25	27.57
3.5	22.33	29.85
4.0	23.23	30.80

3.8	22.15	27.66	29.66	22.51	28.04	30.04	22.87	28.42	30.42	23.23	28.80	30.80	23.9	29.18	31.18
3.9	22.33	27.85	29.85	22.69	28.23	30.23	23.05	28.61	30.61	23.41	28.99	30.99	23.7	29.37	31.37
4.0	22.51	28.04	30.04	22.87	28.42	30.42	23.23	28.80	30.80	23.59	29.18	31.18	23.9	29.56	31.56

備註：1、乳脂率低於2.8%者不予計價，無脂固形物率8.0%以下則不予計價。
2、生乳計價以本表每公斤生乳為基準，其中冬期為每年12月至翌年3月，暖期為4、5、10、11月，夏期為每年6月至9月。

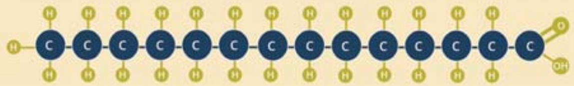
Milk fat and true protein contents are the primary price basis of raw milk on commercial dairy farms

乳脂肪中主要脂肪酸組成分

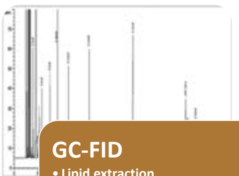
Fatty acid carbon number	Fatty acid common name	Average range (wt%)
4:0	Butyric酪酸	2-5
6:0	Caproic己酸	1-5
8:0	Caprylic辛酸	1-3
10:0	Capric葵酸	2-4
12:0	Lauric月桂酸	2-5
14:0	Myristic肉豆酸	8-14
15:0	Pentadecanoic十五脂酸	1-2
16:0	Palmitic棕櫚酸	22-35
16:1	Palmitoleic棕櫚烯酸	1-3
17:0	Margaric十七脂酸	0.5-1.5
18:0	Stearic硬脂酸	9-14
18:1 [2]	Oleic油酸	20-30
18:2	Linoleic亞麻油酸	1-3
18:3	Linolenic次亞麻油酸	0.5-2

Jensen, 2002

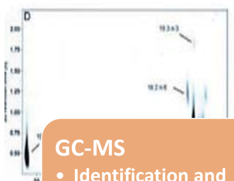
分析乳脂肪酸來源及長中短脂肪酸種類之新科技



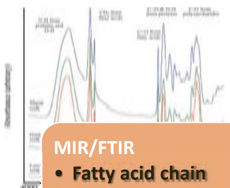
乳脂肪酸檢測技術演變



GC-FID
- Lipid extraction
- Fractionation of lipid classes
- FA derivatization
- Separation and analysis of FA



GC-MS
- Identification and quantification of FA



MIR/FTIR
- Fatty acid chain length
- Milk species

Routine milk measurements

Table. Number of samples, mean of reference value, SD, minimum and maximum values of final population of samples used to develop mid-Fourier transform infrared (mid-FTIR), partial least squares (PLS) prediction models

	Mid-FTIR PLS prediction models			
Item	Total fatty acids	De novo fatty acids	Mixed fatty acids	Preformed fatty acids
Number of samples	268	268	268	268
Mean	3.36	0.83	1.03	1.51
SD	0.9	0.26	0.29	0.41
Minimum	0.19	0.05	0.06	0.08
Maximum	6.15	1.82	2.02	2.51
Number of factors	8	10	9	11
SECV	0.019	0.025	0.047	0.056
R^2	0.999	0.991	0.975	0.981
F-Ratio (PRESS)	1.1623	1.272	1.165	1.105
F-Test (FPRESS)	0.8894	0.975	0.893	0.792
RPD	47.6	10.4	6.2	7.3

Woolpert *et al.*, 2016

Table. Validation comparison of mean difference (MD), standard deviation of the difference (SDD) and relative standard deviation (RSD) of GC measurement of total, de novo, mixed origin, and preformed fatty acids to mid-infrared (IR) partial least square predictions for bulk tank milk samples (n = 40)

	Fatty acids, g/100 g of milk			
Parameter	**Total**	**De novo**	**Mixed**	**Preformed**
Overall IR mean	**3.769**	**0.928**	**1.258**	**1.583**
Overall GC mean	**3.769**	**0.944**	**1.198**	**1.627**
MD (IR – GC)	**0.000**	**-0.016**	**0.060**	**-0.044**
SDD	**0.035**	**0.024**	**0.072**	**0.080**
RSD, %	**0.93**	**2.64**	**5.69**	**5.03**

Woolpert *et al.*, 2016

乳脂肪酸與**飼養管理、營養、乳品質及疾病**的關聯性

動物

- 遺傳
- 泌乳階段
- 瘤胃功能
- 乳房感染
- 使用生長激素

飼糧

- 穀物攝取量
- 脂肪來源與總量
- 蛋白質含量
- 能量含量
- 季節或區域

影響乳脂肪酸變化之相關因素

Jensen, 2002

乳牛飼糧中脂肪來源會顯著影響乳脂肪酸組成

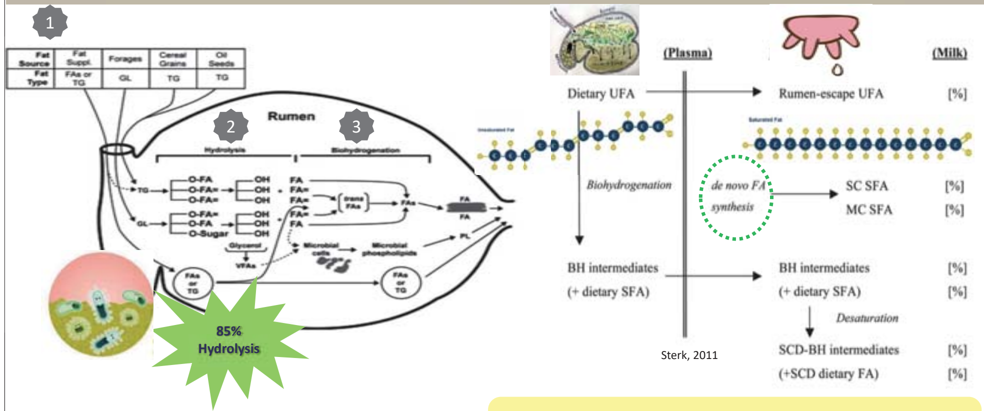


Figure. Lipid metabolism in the rumen including the predominant fat types in common feedstuffs (TG = TAG = triacylglycerides, GL = glycolipids and FA = fatty acids; Bauman and Lock, 2006)

- De novo FA (<16 carbons) originate from mammary de novo synthesis
- Preformed FA (>16 carbons) originate from extraction from plasma
- Mixed FA originate from both sources (C16:0 + C16:1 *cis-9*)

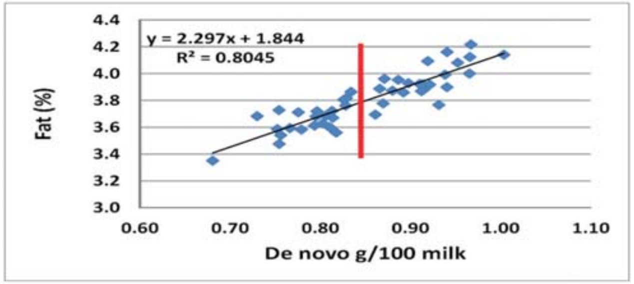


Figure 1. Relationship of bulk tank milk fat test to concentration (g/100 g milk) of de novo FA in milk. In general, a farm needs to have a concentration of de novo FA higher than 0.85 g/100 g milk to achieve a bulk tank fat test higher than 3.75%.

Barbano *et al.*, 2014

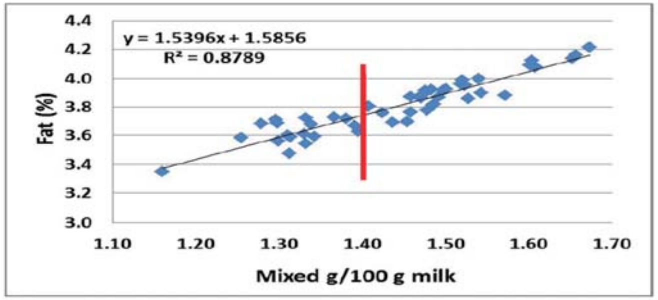


Figure 2. Relationship of bulk tank milk fat test to concentration (g/100 g milk) of mixed origin FA in milk. In general, a farm needs to have a concentration of mixed origin FA higher than 1.40 g/100 g milk to achieve a bulk tank fat test higher than 3.75%.

Barbano *et al.*, 2014

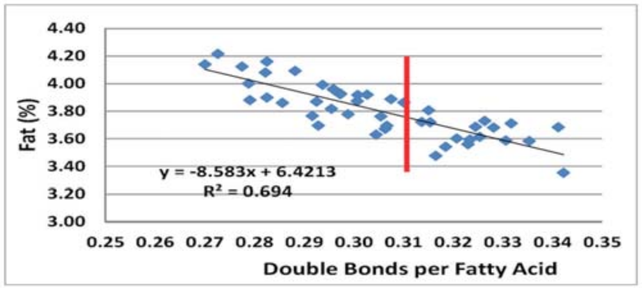


Figure 3. Relationship of bulk tank milk fatty acid unsaturation with bulk tank milk protein test. As double bonds per fatty acid increases the bulk tank milk fat test decreases. To achieve a 3.75 % fat test a farm needs to have a double bond per fatty acid of less than 0.31.

Barbano *et al.*, 2014

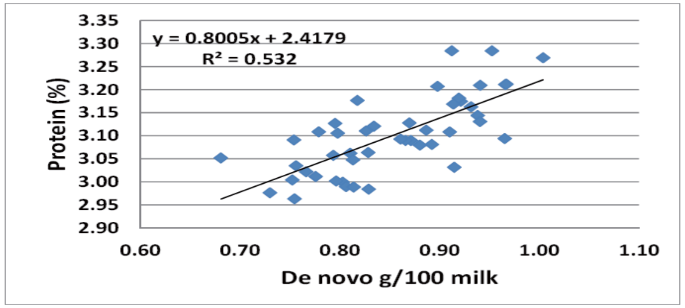


Figure 4. Relationship of bulk tank milk protein concentration with change in de novo milk fatty acid concentration. As de novo milk fatty acid concentration increases milk protein increases.

Barbano et al., 2014

Table. Example of expected changes in milk production and composition for bulk tank milk on corn based total mixed ration fed Holstein cows that are progressive moving into rumen produced trans fatty acid induced milk fat depression

	Fatty acid									
	Milk kg	De novo	Mixed	Preformed	Lactose	Fat	Protein	Fatty acids per 100g fatty acids		
Week	Per day	g/day	g/day	g/day	g/day	g/day	g/day	De novo	Mixed	Preformed
1	41.8	380	589	560	1,927	1,621	1,358	24.86	38.50	36.64
2	41.7	375	563	559	1,930	1,584	1,355	25.06	37.59	37.36
3	41.6	353	541	566	1,921	1,543	1,318	24.22	37.04	38.75
4	41.5	332	519	573	1,915	1,506	1,303	23.32	36.44	40.23
5	41.5	300	477	564	1,911	1,418	1,284	22.40	35.55	42.05

Barbano et al., 2014

Table. Example of expected changes in milk production and composition for bilk tank milk on corn based total mixed ration fed Holstein cows that are progressively experiencing a mammary infection immune system challenge that is characterized by an increase in milk SCC

	Fatty acid									
	Milk kg	De novo	Mixed	Preformed	Lactose	Fat	Protein	Fatty acids per 100g fatty acids		
Week	Per day	g/day	g/day	g/day	g/day	g/day	g/day	De novo	Mixed	Preformed
1	41.8	380	587	568	1,642	1,626	1,358	24.78	38.22	37.00
2	40.9	368	564	564	1,884	1,585	1,324	24.59	37.70	37.70
3	40.0	360	555	551	1,826	1,550	1,290	24.52	37.87	37.60
4	39.0	351	539	547	1,773	1,519	1,269	24.46	37.50	38.04
5	38.1	343	530	530	1,724	1,487	1,243	24.46	37.77	37.77

Barbano et al., 2014

Table. Example of expected changes in milk production and composition for bilk tank milk on corn based total mixed ration fed Holstein cows due to a TMR reformulation where an error in sampling or feed analysis cause the energy density of the new TMR to be lower than old TMR

	Fatty acid									
	Milk kg	De novo	Mixed	Preformed	Lactose	Fat	Protein	Fatty acids per 100g fatty acids		
Week	Per day	g/day	g/day	g/day	g/day	g/day	g/day	De novo	Mixed	Preformed
1	41.8	380	587	568	1,927	1,626	1,358	24.78	38.22	37.00
2	41.8	376	576	576	1,938	1,621	1,353	24.59	37.70	37.70
3	41.7	367	558	592	1,923	1,605	1,334	24.18	36.81	39.01
4	41.5	353	548	589	1,917	1,573	1,320	23.68	36.77	39.55
5	40.9	327	515	589	1,886	1,513	1,297	22.86	36.00	41.14

Barbano et al., 2014

Table. Effects of milking and freestall feeding frequency on bulk tank milk fatty acid composition among high de novo (HDN) or low de novo (LDN) farms

Item	HDN, %	LDN, %	OR[1] (95% CI)	P-value
Milking frequency	63.19	50.00	1.71(0.446.70)	0.59
Time away from pen ≤3 h/d	78.72	75.15	1.22(0.16-9.12)	0.84
Freestall feeding frequency	68.84	30.68	4.99(0.89-27.99)	0.07
Freestall push-up frequency ≥5	29.82	77.10	0.12(0.02-1.02)	0.05
Stall stocking density ≤1.10 cows/stall	65.29	21.35	4.74(0.83-27.21)	0.08
Feed bunk space ≥46 cm per cow	43.71	7.12	10.13(0.91-112.41)	0.06
Tiestall feeding frequency	67.38	42.51	2.79(0.06-134.62)	0.56

Woolpert et al., 2016

Table. Least squares means of dietary chemical composition for diets from high de novo (HDN) and low de novo (LDN) farms [1]

Item	HDN	LDN	SEM	P-value
DM, %	41.7	43.7	1.3	0.23
CP, % of DM	15.6	16.2	0.4	0.29
aNDFom, [2] % of DM	37.8	35.4	1.0	0.20
Ether extract, % of DM	3.7	4.0	0.1	<0.01
Starch, % of DM	22.6	24.3	1.2	0.29

1 Data were mathematically composited by the number of cows that consumed the diet, and analyzed using farm as the experimental unit.
2 Organic-matter-corrected NDF with α-amylase and sodium sulfite.

Woolpert et al., 2016

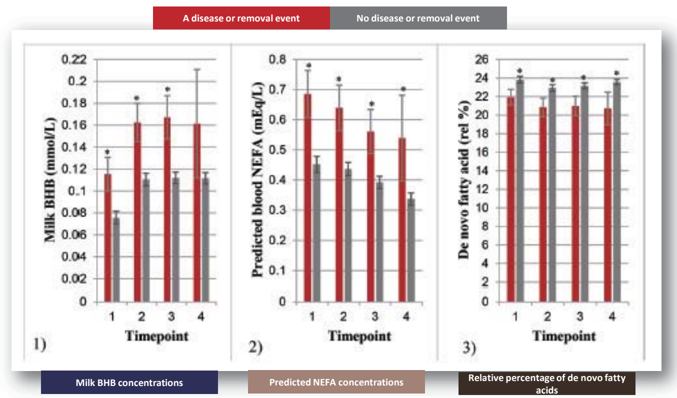


Figure. T-test analyses of mean concentration of Fourier-transform mid-infrared analysis of milk predicted constituents: (1) **milk BHB concentrations**, (2) **predicted blood non-esterified fatty acid (NEFA) concentrations**, and (3) **relative (rel) percentage of de novo fatty acids.** Test population was 457 Holstein cows from 2 herds, **having a disease or removal event (red bars) or no disease or removal event (gray bars) during each sampling timepoint**: timepoint 1 (3 to 7 DIM), timepoint 2 (6 to 11 DIM), timepoint 3 (10 to 14 DIM), or timepoint 4 (13 to 18 DIM). Disease or removal events were defined as any of the following occurring on or following the day of sampling and within the first 30 DIM: cow was sold, died, or was diagnosed with metritis, displaced abomasum, or blood BHB concentration ≥1.2 mmol/L (between 3 and 18 DIM). Error bars represent 95% confidence intervals. P-value reported for Bonferroni corrected t-statistic: *P < 0.004; all others P = 0.2.

Bach *et al.*, 2019

總結

- 利用傅立葉紅外線光譜法(FTIR)可快速準確的檢測出脂肪酸來源及種類。
- 生乳之長中短鏈脂肪酸變化，可作為洞察牛群飼養管理、營養或疾病等之指標。
- 持續收集國內生乳各項脂肪酸資料，並分析其關聯性及應用。

THANK YOU