

牛乳中尿素氮、檸檬酸含量與乳組成和乳熱安定性的相關⁽¹⁾

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摘 要

本試驗欲明瞭牛乳中尿素氮、檸檬酸含量與乳組成及乳熱安定性的相關，期提供酪農提升生乳品質之參考。抽樣測定酪農牛總乳之乳脂肪、蛋白質、酪蛋白、乳清蛋白、乳糖、總固形物、尿素氮、檸檬酸含量及pH、乳酸度、體細胞數等，其中尿素氮與檸檬酸平均各為 16.3 mg/dl (範圍 5.3 ~ 40.1 mg/dl)、151.4 mg/dl (範圍 119~190 mg/dl)，依尿素氮含量分為<10 mg/dl、10~20 mg/dl 及>20 mg/dl 三組，另依檸檬酸含量分為<110 mg/dl、110~150 mg/dl 及>150 mg/dl 三組，pH介於 6.6 至 6.8 間，分別於 140°C 油浴 1 分鐘，均未產生凝固或沉澱，即不影響乳之熱安定性。相同乳樣測定其 α_{s1} 、 α_{s2} 、 β 及 κ -酪蛋白，總鈣、游離鈣與總磷含量，三組間並無顯著差異。並統計尿素氮、檸檬酸含量與上述乳組成及pH的相關，結果尿素氮與 α_{s1} -酪蛋白呈顯著負相關 ($P<0.05$)，而檸檬酸與乳脂肪、蛋白質、總固形物、pH均呈顯著負相關 ($P<0.05$)。

關鍵詞：牛乳、尿素氮、檸檬酸、乳熱安定性。

緒 言

研究牛乳熱安定性的報告很多，但有關熱凝固之機制仍未完全明瞭，有認為與 β -乳球蛋白及 κ -酪蛋白量有關，添加 β -乳球蛋白於脫脂乳，乳熱安定性下降，添加 κ -酪蛋白，則乳熱安定性上升 (Muir and Sweetsur, 1978)，與 β -乳球蛋白及 κ -酪蛋白遺傳變異體有關 (Feagan *et al.*, 1972)，與蛋白質含量有關 (Bartsch *et al.*, 1979)，但與蛋白質組成無關 (Kelly *et al.*, 1982; Morrissey *et al.*, 1981)，與季節有關 (Holt *et al.*, 1978 a)，也有認為pH、鹽類平衡、乳清蛋白及酪蛋白膠粒 (casein micelle) 之交互作用為主要影響因素 (McCrae and Muir, 1995; Singh and Creamer, 1992)。羊乳方面早期之研究即指陳羊乳對超高溫 (ultra high temperature, UHT) 之熱處理比牛乳敏感 (Fox and Hoynes, 1976; Thompson *et al.*, 1969)，羊乳之熱凝固時間比牛乳者短，可能與羊乳之低pH、酪蛋白、檸檬酸有關 (Allgower and Bachmenn, 1990)，或與鹽類平衡 (Ram and Sindhu, 1991)、羊乳 α_{s1} -酪蛋白遺傳變異體 (Tziboula, 1997)、離子性鈣量 (Montilla and Calvo, 1997) 有關，而Morgan *et al.* (2000) 報告，羊乳pH、總

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磷與乳清蛋白較高，而離子性鈣量較低之乳熱安定性較佳。

牛乳中尿素氮量會受日糧 (Baker *et al.*, 1995 ; Jonker *et al.*, 1998 ; Godden *et al.*, 2001 a ; Godden *et al.*, 2001 b)、季節及泌乳期 (Carlsson *et al.*, 1995) 之影響，而乳中尿素氮量與乳牛利用日糧中粗蛋白質及熱能之效率有關 (Godden *et al.*, 2001b ; Jonker *et al.*, 1998)，且與乳牛繁殖性能有關 (Melendez *et al.*, 2000 ; Witter *et al.*, 1999)，為近年國外研究乳牛營養重視項目之一。Muir and Sweetsur (1976) 認為 40%牛乳之熱安定性的變異與乳中尿素氮量有關，添加尿素於牛乳中，使乳尿素氮量介於 19~45 mg/dl 之間，其熱安定性比未添加尿素者佳，而移去尿素牛乳之熱凝固時間比未移去者差，乳中尿素氮含量愈高者熱安定性愈佳。而 Banks *et al.* (1984) 添加 0~10 mg/dl 尿素於乳中，發現含較低尿素氮之牛乳熱凝固時間較短。常乳之熱安定性，除尿素氮外，與其他乳成分均無顯著相關 (Holt *et al.*, 1978 b)。

檸檬酸鹽為乳腺泌乳細胞所分泌 (Konar *et al.*, 1971)，檸檬酸鹽扮演平衡乳中礦物質之角色，檸檬酸可以游離態或與礦物質如鈣、磷結合，90%以上之檸檬酸鹽存在液相乳中，僅 7%與鈣-酪蛋白結合為複合物 (Davies and White, 1960)。於乳正常 pH 時，極少以游離態或單價檸檬酸鹽存在，一般以三價檸檬酸鹽或二價檸檬酸鹽存在，三價檸檬酸鹽與二價檸檬酸鹽之比為 1.6:1，而 pH 改變時，此比率會改變。檸檬酸能與磷酸鹽共成重要之緩衝作用，且與鈣、鎂成複合物，因此，檸檬酸含量會影響乳中鈣之分布，而酪蛋白與鈣以一定比例結合，若乳中游離鈣低時，酪蛋白膠粒變小，而游離鈣上升時，酪蛋白不安定 (林, 1993)。添加 20 mg/dl 離子性鈣，則牛乳熱凝固時間縮短 (Schaar, 1984)。檸檬酸為牛乳自然酸度組分之一 (張, 1983)，當牛乳酸度低時，乳中脂肪、蛋白質、乳糖量均減少 (李及陳, 1991)，酒精不安定乳之檸檬酸及乳糖含量較低，也與牛乳之熱安定性有關 (林, 1993)。牛乳檸檬酸含量會受日糧 (Chaiyabutr *et al.*, 1981 ; Faulkner and Chapperton, 1981) 及季節 (Faulkner and Peaker, 1982) 的影響，且泌乳末期比初期者低，又與體細胞數呈顯著負相關 (Konar *et al.*, 1971 ; Peaker and Linzell, 1975)，潛在性乳房炎時檸檬酸含量降低 (Oshima and Fuse, 1981)。羊乳之檸檬酸含量比牛乳少 25%，可能為羊乳熱凝固時間比牛乳較短之因 (Allgower and Bachmenn, 1990)。

本試驗即欲探討乳中尿素氮、檸檬酸含量與乳組成及乳熱安定性的相關，期提供酪農提升生乳品質之參考。

材料與方法

- I. 試驗材料：利用桃園縣、苗栗縣與嘉義縣酪農所產之總乳。
- II. 分析方法：利用乳成分與體細胞合併測定儀 Milk Scan 4000 及 Fossomatic 5000 (FOSS 公司，丹麥製) 檢測乳脂肪、蛋白質、乳糖、總固形物、尿素氮、檸檬酸含量與體細胞數等。利用 Corning pH and ion meter (Corning, 英國製) 依常法測 pH 及滴定酸度 (中國國家標準, 1982)。取定量乳樣封口，37°C 預熱後，140°C 油浴 1 分鐘，記錄產生顆粒或凝固之時間 (Davies and White, 1966)。相同乳樣以毛細管電泳法分離乳蛋白質，依 Cattaneo *et al.*, 1996 法稍修正之。等電點 pH 4.6 使酪蛋白沉澱，測酪蛋白及乳清蛋白質量。測定乳中總鈣量 (IDF, 1992)。添加凝乳酶測定游離鈣量，測定乳中總磷量 (IDF, 1990)。
- III. 統計分析：利用 EXCEL 2000 (1985~1999) 軟體統計各測值之平均值及其相關係數。

結果與討論

利用桃園縣、苗栗縣與嘉義縣酪農所產之總乳，樣品數分別為 55、145 及 154，分析所有乳樣（ $n = 354$ ）之乳脂肪、蛋白質、乳糖、酪蛋白、乳清蛋白、總固形物、尿素氮及檸檬酸含量、pH、酸度與體細胞數等，其平均分別為 $3.65 \pm 0.20\%$ 、 $3.10 \pm 0.16\%$ 、 $4.64 \pm 0.27\%$ 、 $2.49 \pm 0.12\%$ 、 $0.70 \pm 0.14\%$ 、 $11.47 \pm 0.55\%$ 、 $16.3 \pm 8.4 \text{ mg/dl}$ 、 $151.4 \pm 10.7 \text{ mg/dl}$ 、 6.77 ± 0.08 、 $0.124 \pm 0.08\%$ 及 40 ± 19 ($\times 10^4/\text{ml}$) 等，其中尿素氮及檸檬酸範圍各為 $5.3 \sim 40.1 \text{ mg/dl}$ 及 $119 \sim 190 \text{ mg/dl}$ 。

總乳尿素氮範圍為 $5.3 \sim 40.1 \text{ mg/dl}$ ，含量低於 10 mg/dl 者佔 13.6%，分別選取 $< 10 \text{ mg/dl}$ 、 $10 \sim 20 \text{ mg/dl}$ 、 $> 20 \text{ mg/dl}$ 尿素氮含量之總乳樣品，乳之 pH 範圍 $6.6 \sim 6.8$ ， 140°C 油浴 1 分鐘，均未產生凝固或沉澱，即不同濃度之尿素氮量不影響乳之熱安定性。而 Muir and Sweetsur (1976) 添加尿素於乳中，使乳之尿素氮量介於 $19 \sim 45 \text{ mg/dl}$ 之間，其熱安定性比未添加者佳，而移去尿素牛乳之熱凝固時間比含尿素者差。而 Banks *et al.* (1984) 試驗添加 $0 \sim 10 \text{ mg/dl}$ 尿素於乳中試驗，也發現含較低尿素氮量牛乳之熱凝固時間較短。顯示本試驗於正常乳之尿素氮量下不致影響乳之熱安定性。相同乳樣測定其 α_{s1} 、 α_{s2} 、 β 及 κ -酪蛋白、總鈣、游離鈣與總磷含量等，三組間除 pH 外並無顯著差異（表 1）。統計彼此間相關，僅尿素氮與 α_{s1} -酪蛋白呈顯著負相關（ $P < 0.05$ ）。

表 1. 不同尿素氮含量之乳組成

Table 1. Milk components at various contents of milk urea nitrogen

Item	Milk urea nitrogen (mg/dl)		
	< 10	10-20	> 20
No. of samples	10	20	5
Fat (%)	3.72 ± 0.81	3.58 ± 0.21	3.65 ± 1.00
Protein (%)	3.10 ± 0.11	3.17 ± 0.22	3.09 ± 0.14
Lactose (%)	4.61 ± 0.12	4.59 ± 0.15	4.68 ± 0.14
Total solids (%)	11.45 ± 0.42	11.58 ± 0.34	11.61 ± 0.50
Casein (%)	2.51 ± 0.14	2.60 ± 0.12	2.61 ± 0.11
Whey protein (%)	0.59 ± 0.05	0.57 ± 0.04	0.55 ± 0.08
α_{s1} -casein (%)	54.40 ± 3.50	52.40 ± 5.10	52.70 ± 1.80
α_{s2} -casein (%)	10.40 ± 2.20	11.00 ± 2.60	10.90 ± 1.50
β -casein (%)	28.40 ± 5.40	29.10 ± 4.50	30.10 ± 6.10
κ -casein (%)	5.80 ± 2.10	5.50 ± 1.50	6.00 ± 1.80
Citric acid (mg/dl)	149.20 ± 10.50	152.00 ± 11.90	151.40 ± 9.20
Ca _{total} (mg/dl)	120.00 ± 18.50	125.00 ± 22.10	130.10 ± 25.10
P _{total} (mg/dl)	95.00 ± 12.50	89.60 ± 15.70	95.40 ± 13.10
Ca _{soluble} (mg/dl)	51.80 ± 5.20	53.10 ± 2.50	52.10 ± 3.50
pH	6.64 ± 0.04^a	6.67 ± 0.05^b	6.70 ± 0.06^c
Acidity (%)	0.014 ± 0.002	0.013 ± 0.005	0.012 ± 0.003
Somatic cell count ($\times 10^4/\text{ml}$)	35.00 ± 19.00	41.00 ± 21.00	38.00 ± 19.50

^{a, b, c} Means with the different superscripts differ significantly ($P < 0.05$).

牛總乳尿素含量之範圍， $19 \sim 45 \text{ mg/dl}$ (Muir and Sweetsur, 1976)， $20 \sim 60 \text{ mg/dl}$ (Holt *et al.*, 1978 b)， $35.9 \sim 50.3 \text{ mg/dl}$ (Banks *et al.*, 1984)， $27.9 \sim 55.2 \text{ mg/dl}$ (Eicher *et al.*, 1997)，均比本試驗之 $5.3 \sim 40.1 \text{ mg/dl}$ 高。而 Nelson (1997) 4 個牛群平均各為 13.4、13.6、13.8、13.9 mg/dl，Higginbotham *et al.* (1998) 5 個牛群平均各為 12.7、15.0、15.0、15.5 及 16.5 mg/dl，比本試驗之平均 $16.3 \pm 8.4 \text{ mg/dl}$

相近或稍低。

近年許多研究利用總乳之蛋白質與尿素氮含量，來評估日糧提供乳牛之粗蛋白質及熱能是否恰當 (Godden *et al.*, 2001b; Jonker *et al.*, 1998) 或評估乳牛之繁殖性能，許多報告認為乳尿素氮含量 19 mg/dl 為影響母牛繁殖效率的關鍵量，超過者其受孕率低 (Butler *et al.*, 1996; Quaife, 1994)。本試驗總乳尿素氮含量 > 20 mg/dl 者佔 6.4 %。總乳為牛群個別牛乳之平均，顯示，本試驗部分個別牛乳之尿素氮含量超過 19 mg/dl，而由尿素氮及乳蛋白質含量可判定日糧提供之粗蛋白質不足或過多，或熱能不足或過多，國內應重視乳中尿素氮含量問題。

檸檬酸平均 151.4 mg/dl，範圍 119~190 mg/dl，含量比 Konar *et al.* (1971) 之平均 170 mg/dl 為低，但與 Sato *et al.* (1998) 之平均 150 mg/dl 相近。檸檬酸含量 < 110 mg/dl 者佔 8.1%，110~150 mg/dl 之比例最高佔 88.0%，> 150 mg/dl 者僅佔 3.9%，依此標準分為三組，乳之 pH 範圍 6.6~6.8，於 140°C 油浴 1 分鐘，均未產生凝固或沉澱，即檸檬酸含量高或低不影響熱安定性。同時測定乳中總鈣、游離鈣與總磷含量，三組間除 pH 外均無顯著差異 (表 2)。檸檬酸與乳脂肪、蛋白質、總固形物、pH 等呈顯著負相關 ($P < 0.05$)，但與乳體細胞數無顯著相關，而 Konar *et al.* (1971) 及 Peaker and Linzell (1975) 試驗，檸檬酸與體細胞數呈顯著負相關。

表 2. 不同檸檬酸含量之乳組成

Table 2. Milk components at various contents of milk citric acid

Item	Milk citric acid (mg/dl)		
	< 110	110-150	> 150
No. of samples	10	20	5
Fat (%)	3.62 ± 0.81	3.52 ± 0.21	3.65 ± 1.00
Protein (%)	3.12 ± 0.09	3.15 ± 0.13	3.17 ± 0.15
Lactose (%)	4.59 ± 0.10	4.62 ± 0.13	4.65 ± 0.15
Total solids (%)	11.50 ± 0.42	11.55 ± 0.34	11.65 ± 0.50
Casein (%)	2.57 ± 0.13	2.59 ± 0.16	2.60 ± 0.11
Whey protein (%)	0.59 ± 0.05	0.59 ± 0.06	0.55 ± 0.08
α_{s1} -casein (%)	55.40 ± 3.60	54.60 ± 4.10	54.70 ± 1.80
α_{s2} -casein (%)	11.50 ± 2.20	10.80 ± 2.60	10.70 ± 1.50
β -casein (%)	28.00 ± 4.40	29.10 ± 5.00	30.50 ± 6.10
κ -casein (%)	6.30 ± 2.10	5.70 ± 1.50	6.00 ± 1.80
Urea nitrogen (mg/dl)	15.40 ± 7.50	16.10 ± 8.10	15.80 ± 4.80
Ca _{total} (mg/dl)	120.00 ± 16.50	123.00 ± 13.10	128.10 ± 18.10
P _{total} (mg/dl)	93.00 ± 12.30	93.60 ± 13.70	94.40 ± 13.10
Ca _{soluble} (mg/dl)	52.80 ± 5.20	53.20 ± 2.50	52.10 ± 3.50
pH	6.63 ± 0.04 ^a	6.65 ± 0.05 ^b	6.67 ± 0.06 ^c
Acidity (%)	0.013 ± 0.004	0.014 ± 0.005	0.012 ± 0.003
Somatic cell count ($\times 10^4$ /ml)	40.00 ± 20.00	45.00 ± 15.00	42.00 ± 19.50

^{a, b, c} Means with the different superscripts differ significantly ($P < 0.05$).

結 論

乳之 pH 在 6.6 至 6.8 之間，牛乳中尿素氮與檸檬酸含量分別介於 5.3~40.1 mg/dl 及 119~190 mg/dl 之間時，不影響乳熱安定性。尿素氮量與 α_{s1} -酪蛋白量呈顯著負相關 ($P < 0.05$)，且檸檬酸與乳脂肪、蛋白質、總固形物、pH 均呈顯著負相關 ($P < 0.05$)。

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Association of concentration of milk urea nitrogen and citric acid with milk components and heat stability⁽¹⁾

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Abstract

The purpose of this experiment was to discern the relationships of the content of milk urea nitrogen and citric acid with milk components and heat stability. Bulk cow milks were randomly sampled. The content of milk fat, protein, casein, whey protein, lactose, total solids, urea nitrogen, citric acid and value of pH, acidity and somatic cell count were examined. The means of urea nitrogen and citric acid were 16.3 mg/dl (range 5.3 to 40.1 mg/dl) and 151.4 mg/dl (range 119 to 190 mg/dl), respectively. Milk was grouped into three categories based on urea nitrogen. The categories were <10, 10~20 and >20 mg/dl, respectively. Milk was also grouped into three categories based on milk citric acid as <110, 110~150 and >150 mg/dl. Range of milk pH value was 6.6~6.8. Milk samples were sealed in glass tubes and heat treatment was performed in an oil bath at 140°C for 1 min. There was not any sediment or coagulation in treated milk. Milks were also tested for the concentration of α_{s1} , α_{s2} , β and κ -casein, total calcium, total phosphorus and soluble calcium. But no significant difference was found among those factors. However, there was significant negative correlation between urea nitrogen and α_{s1} -casein ($P < 0.05$) and significant negative difference among milk citric acid, milk fat, protein, total solids and pH value ($P < 0.05$).

Key words : Cow milk, Urea nitrogen, Citric acid, Heat stability.

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