IMPACT OF FORAGE QUALITY AND HEAT STRESS ON MILK COMPOSITION AND CHEDDAR CHEESE YIELD

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SUMMARY

The experiment assessed the effects of forage quality and heat stress on milk composition and Cheddar cheese yield efficiency. The experimental design was a 4 x 4 latin square, with 7-day adjustment periods followed by 5 days of sample collection. The treatments were: 1) high quality lucerne chaff-based diet plus cooling (sprinkler and shade) (HD+C), 2) high quality lucerne chaff-base diet without cooling (HD-C), 3) low quality lucerne chaff-based diet with cooling (LD+C), and 4) low quality lucerne chaff-based diet without cooling (LD-C; control). Animals were restricted to the same forage intake as the control treatment, and they all received 4.2 kg concentrates daily. Diets were fed in the form of total mixed rations and were balanced for protein using cottonseed meal. Cooling reduced body temperature by 1°C and increased milk yield by 0.5 L/day/cow (P< 0.05). Milk fat plus casein contents were affected by a combination of diet and cooling (P<0.05). The proportion of α_{s2}–casein in the total casein increased from 7.9 to 8.7% for the control and cooling treatments, respectively (P< 0.05). Cheese yield efficiency (i.e. adjusted cheese yield per 100 kg milk divided by theoretical yield x 100) for the HD+C treatment was greater by 1%, 5% and 9% compared with HD-C, LD+C and LD-C treatments, respectively (P< 0.05).

Keywords: milk processability, Cheddar cheese manufacture, forage, cow cooling

INTRODUCTION

In south-east Queensland, milk protein content and cheese yield fall during summer months, and these variations are related to variations in milk fat and protein content. Often, there is a decline in protein concentration below levels set by the processing factories and the standard (3.0% m/v true protein) set by the Australian and New Zealand Food Authority (ANZFA 2000), resulting in reduced income for processors via impacts on cheese yield efficiency. Milk casein is highly correlated to cheese yield. For instance, on average, a 0.1% reduction in total casein concentration reduces Cheddar cheese yield potential by 0.5 kg/100 kg milk (Christian *et al*. 1999; Guinee *et al*. 2001), which means an economic loss of $6.million to a cheese manufacturer processing 200 ML of milk a year.

During heat stress, when intake by the cow is reduced, and maintenance requirement is increased, body protein may be metabolised to meet the cow's energy needs. Consequently, less protein is available for productive functions (Beede 1993; Cowan 1994; Huber *et al*. 1994). These changes may be expected to have negative effects on milk yield, chemical composition of the milk, and both cheese yield and yield efficiency. This experiment was designed to assess the effects of forage quality and heat stress during the hotter months on the suitability of the resulting milk for Cheddar cheese manufacture.

MATERIALS AND METHODS

Experimental design and treatments

The experiment was a 4 (2 forage quality-based diets x 2 cooling systems) x 4 latin square, with 7-day adjustment periods followed by 5 days of sample collection. Four multiparous Holstein-Friesian cows in late lactation (234 ± 28 days in milk) were selected from the University of Queensland, Gatton, dairy herd. Cows were matched for parity, milk production, protein phenotype (α_{S2}-casein BB, κ-casein BB and ß-Lg BB) and individually stalled, milked and fed twice daily at 0630 and 1530 h. The treatments were: 1) high quality lucerne chaff-based diet plus cooling (sprinkler and shade) (HD+C), 2) high quality lucerne chaff-base diet without cooling (HD-C), 3) low quality lucerne chaff-based diet with cooling (LD+C), and 4) low quality lucerne chaff-based diet without cooling (LD-C; control).

All animals were restricted to the same forage intake as the LD-C treatment, and received 4.2 kg concentrates daily. Diets were fed in the form of total mixed rations (TMR) and were balanced for protein using cottonseed meal. Dry matter intake, water consumption, milk yield, ambient temperature at 0630 and 1530 h, relative humidity and each cow's rectal temperature were recorded daily. Temperature Humidity Index (THI) values were calculated according to Wiersama (1990) using the afternoon ambient temperature, and relative humidity recorded for shaded and unshaded areas. The cooling system included use of shade, electric fans (24 hours) and the application of a computer-controlled sprinkling system with a 5-minutes-on-5 minutes-off cycle for 4 hours, from 1200 to 1600 h every day. Water droplets were delivered from garden sprinklers set at a height of 1.5 m along the backs of the experimental cows. The HD-C and LD-C cows were maintained in open pens.

The TMR was fed at 90% of the *ad libitum* intake of the control treatment (Table 1). The diets were composed of 70% lucerne chaff and 30% concentrate. The high and low quality diets contained 20 and 18.5% crude protein, and 10.5 and 9.5 MJ of metabolisable energy/kg DM, respectively. Water was continuously available.

Table 1. Average daily dry matter, energy and crude protein intake.

	High quality diet		Low quality diet		
	Cooling	No cooling	Cooling	No cooling	SE
DM intake (kg/cow/day)	15.0	15.0	15.0	15.0	0.000
ME intake (MJ/cow/day)	158	158	144	144	4.041
Crude protein (CP) intake (kg/cow/day)	3.0	3.0	2.8	2.8	0.058
Apparent digestible CP intake (kg/cow/day)	2.1	2.1	2.0	2.0	0.029
NE Lactation (MJ/cow/day)	98	98	88	88	2.887

Sampling procedures and analysis

Milk gross compositional analysis was performed following the procedures described by the Standards Association of Australia (1998). Individual casein components, α_{s1}-, α_{s2}-, ß- and κ-casein, were determined according to Visser *et al.* (1991) using reversed-phase HPLC. Nitrogen content was converted to protein content using the factor, 6.38, for total protein and casein. The factor, 6.30, was applied to whey protein. Cheesemaking was performed as described by Mayes and Sutherland (1984). Cheese yield was adjusted for moisture, salt, casein, fat, and fat recovery. Target values were experiment means: 3.7% fat in milk, 2.5% casein in milk, 37.3% moisture and 1.6% salt in cheese, 87.0% fat recovery, and 7.0% whey solids. Adjusted Cheddar cheese yield efficiency (Adj Yef) was calculated using the modified Van Slyke and Publow formula as quoted by Mistry *et al.* (2002).

RESULTS AND DISCUSSION

Ambient temperatures in the shaded and unshaded environment at the am recording were similar. However, the temperatures recorded in the afternoon were reduced by approximately 10°C by the cooling (Table 2). The observed value was very similar to the thermal comfort zone for productive dairy cows (5 to 25ºC) previously reported by Armstrong (1993). The pm relative humidity showed a similar increase (approximately by 25%) to the am recorded values for shaded and unshaded environment. Cooling reduced rectal temperature by 1°C and water intake by 7 L daily (Table 2). A significant relationship was found between rectal temperature, ambient temperature and THI. Reductions of the afternoon THI by 12 units, and rectal temperature by 1°C, were associated with an increase in milk yield of 0.5 L. The lower rectal temperatures observed for cows that received cooling demonstrated the effectiveness of cooling when the weather is hot to improve the thermal status of animals.

Cows receiving cooling produced significantly more milk than cows receiving no cooling, but diets had no effect (Table 3). Milk composition was affected by cooling and diet x cooling interactions (Table 3). The fat percentage was higher for cows given the high quality diet and a cooling system than all other treatments. Fat plus casein percentage was higher for cows given the high quality diet and a cooling system, intermediate for cows given either a high quality diet or a cooling system, and lowest for cows on a low quality diet without a cooling system. Ash was increased with the high quality diet.

The proportion of individual caseins in total casein was also affected by the treatment. The proportion of α_{s2}-casein increased from 7.9% for cows receiving no cooling to 8.7% for cows receiving cooling. For cows receiving cooling, the proportion of κ-casein was 14.8 and 16.1% for the high and low quality diets, respectively. There was no effect for cows without cooling. Christian *et al.* (1999) reported a significant increase in α_{S2}-casein (and decline in α_{S1}-casein) when cows were fed a lupinswheat concentrate supplement compared with a control diet (40% silage and 60% pasture hay). Cows that received a high energy and protein diet also exhibited lower κ-casein. Increasing the concentrate level in a diet has also been shown to increase the proportion of α_{S2}-casein and ß-casein (DePeters and Cant, 1992). Interestingly, in our experiment all cows received the same level of concentrate, but still showed variations in the proportions of individual caseins in their milk.

Table 2. Ambient temperature, relative humidity and temperature humidity index (THI) in shaded and unshaded areas, and rectal temperature and water intake of cows during the experiment.

	High quality diet		Low quality diet		
	Cooling	No cooling	Cooling	No cooling	SE
		Ambient temperature (^0C)			
Morning	21.0	20.8	21.0	20.8	0.599
Afternoon	26.0^b	35.0^a	26.0^b	35.0^a	0.732
		Relative humidity (%)			
Morning	48.0	57.0	48.0	57.0	2.735
Afternoon	65.0	72.0	65.0	72.0	2.394
THI (afternoon)	74.0	86.0	74.0	86.0	3.464
		Rectal temperature (^0C)			
Morning before milking	37.9	37.8	37.7	37.7	0.086
Morning after milking	38.1	38.0	37.9	37.9	0.081
Afternoon before milking	37.9^b	39.0^a	37.8^b	38.9^a	0.161
Afternoon after milking	38.1^b	39.0^a	38.0^b	39.0^a	0.147
Water intake (L/cow/day)	103^b	106^a	100^b	110^a	1.657

Values with different superscripts within rows are significantly different (P<0.05).

Table 3. Treatment effects on milk yield and composition.

	High quality diet		Low quality diet		
	Cooling	No cooling	Cooling	No cooling	SE
Milk yield (L/cow/day)	15.0^a	14.4^{ab}	14.6^a	14.3^b	0.169
		Milk component (concentration %, m/m)			
Fat	4.2^a	3.6^b	3.5^b	3.6^b	0.164
Protein	3.2^a	3.1^a	3.2^a	3.2^a	0.121
Casein	2.5^a	2.4^a	2.5^a	2.4^a	0.121
Fat plus casein	6.73^a	6.04^{ab}	5.96^b	5.87^c	0.048
Ash	0.76^a	0.76^a	0.75^b	0.75^b	0.003

Values with different superscripts within rows are significantly different (P<0.05).

Milk from cows in the HD+C group produced significantly more cheese/100 kg milk, with a higher moisture-salt-casein-fat (MSCF) adjusted yield (AdjY) and yield efficiency (Adj Yef) than milks from the other treatments (Figure 1). Cheese yields and yield efficiencies were 11.00, 100; 10.80, 99; 10.51, 95; and 10.00, 91 for milks from HD+C, HD-C, LD+C and LD-C treatments, respectively.

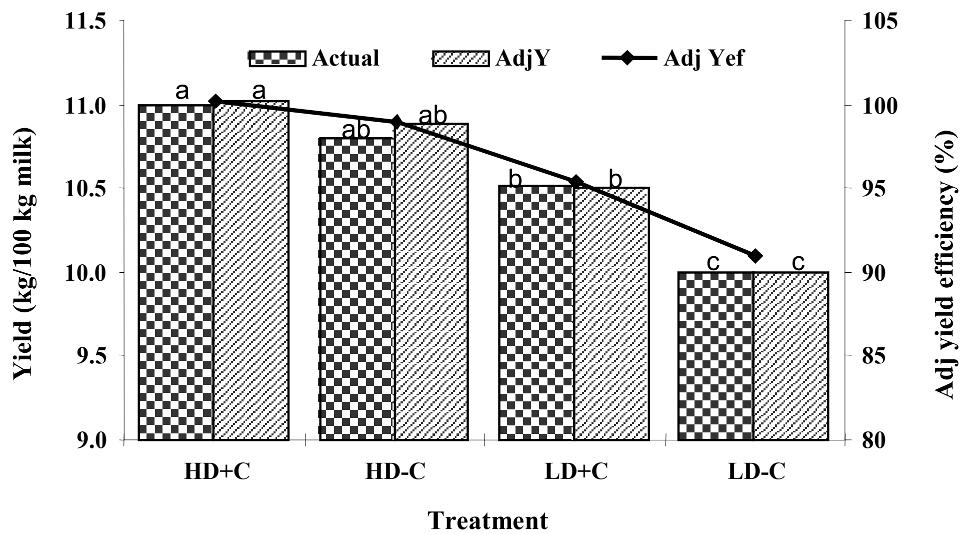

Figure 1. Effect of diet quality and cooling (see text for details) on Cheddar cheese yield and cooling efficiency.

Cheese yields were linearly related to milk fat and casein levels by the equation: cheese yield = 1.53 + 0.79 milk fat% + 2.50 milk casein% (r.s.d. = 0.425; r^2 = 0.73). Lowest yields and efficiencies were recorded for cows on the LD-C treatment. Milk from cows in the LD+C group gave a similar cheese yield to the HD-C milk, but significantly higher than milk from the control group. Adjusted yields were very similar to actual yields. Thus, there appeared to be an additive effect of cooling and diet quality on Cheddar cheese yield efficiency. These results may reflect the significantly higher κ-casein percentage in the LD+C milk and the higher α_{S2}-casein content of the milk from the cooled cows (Dickson and Perkins 1971; Grandison *et al.* 1985).

CONCLUSIONS

Cooling of cows during hot summer days significantly reduced cow temperature and increased milk yield. Cooling, in combination with a high quality diet, significantly increased fat plus casein content in the milk and led to higher Cheddar cheese yield and yield efficiency. These effects may be partly attributable to observed differences in the proportions of α_{s2}- and κ-casein. Thus, providing cows with cooling and a high quality diet when the weather is hot can improve the suitability of milk for Cheddar cheese manufacture.

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