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Silage-Making and Recent Trend of Dairy Farming in Thailand

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Abstract

Based on statistical data such as the number of cattle head, the amount of raw milk production and demand, regional and monthly quantity of raw milk production, etc., the characteristics of dairy farming in Thailand were outlined. It is suggested that feeding of good-quality silage throughout a year is the most effective method to increase the amount of raw milk production in Thailand. However, the difficulty in making good-quality silage in Thailand was pointed out from the results of analyses of the microbial flora of the silages prepared in Thailand. Therefore, the selection of suitable lactic acid bacteria by using an evaluation system of lactic acid bacteria for silage-making in Thailand was proposed.

Discipline: Animal industry
Additional key words: silage, lactic acid bacteria (LAB)

Introduction

Dairy farming, mainly for milk production, was not popular in Thailand until recent years. In the 1950s, dairy farming was implemented by the government through the support of Denmark and Germany and in the 1960s, the government aimed at promoting raw milk production despite the problems of lactation in the tropical zone environment[5]. However, raw milk production in Thailand did not achieve a remarkable development mainly due to problems of milk preservation and bacterial contamination.

In contrast, the demand for raw milk and fermented milk products is rapidly increasing due to the improvement of the life style associated with the growth of the economy in the 1980s. Namely, main energy consumption changed from plant materials such as starch to animal products such as meat and milk. Furthermore, this increase was backed up by the promotion by the government of milk drinking for schoolchildren. Dairy farming as well as the livestock industry is recognized as an important industry under the future strategy for agriculture enacted by the Thai government, while the importance of agricultural products such as rice, cassava and sugar is being less emphasized presently in Thailand. This national project is referred to as “Plan of dairy farming development”. Through the support of the project, technology for dairy farming is making steady progress and the amount of raw milk production is increasing.

In the department stores, supermarkets and convenience stores, many kinds of milk and milk products are displayed, reflecting the rapid increase in the demand for dairy products in Thailand, mainly in urban areas. However, the self-sufficiency ratio in raw milk production is low, accounting for about 50% of the demand, in spite of the efforts to increase raw milk production. Furthermore, Thailand will have to cope with the liberalization of the import of dairy products in 2005. The increase of the amount of raw milk production is a major problem and the Thai government (Department of Livestock Development) plans to increase the amount of raw milk production.

In this paper, recent statistical data of the number of

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milking cattle, the amount of raw milk production and demand in Thailand, and the regional and monthly quantity of raw milk production were analyzed. Furthermore, the characteristics of the microbial flora in the silages prepared in Thailand were also examined. Based on these data, the future development of dairy farming in Thailand will be discussed. Milk productivity of dairy cattle basically depends on inherited lactation ability and can be improved by breeding techniques. Diseases and pests also exert an adverse effect on raw milk production. However, since these problems can not be easily analyzed, policies and environmental problems related to dairy farming will be omitted in this paper.

Materials and methods

1. Microbiological analysis

The number of microorganisms in silage was determined by the plate culture count method[1]. Silage samples (10 g) were shaken well with 90 mL of sterilized distilled water, and 10^{-1}~10^{-6} serial dilutions were made in a 0.85% sodium chloride solution. Lactic acid bacteria (LAB) were counted on an agar plate of Lactobacilli MRS broth (Difco, USA) after incubation in an anaerobic box (Mitsubishi Gas Chemical Co., Inc., Japan) at 45ºC for 24 h. Aerobic bacteria were counted on an agar plate of nutrient broth (Difco, USA) after incubation at 37ºC for 24 h. Yeasts and molds were counted on a plate of potato-dextrose agar (Nissui Seiyaku Ltd., Japan) after incubation at 30ºC for 24 h. Entero-bacteria were counted on a plate of violet red bile agar with lactose (Difco, USA) after incubation at 37ºC for 24 h. Colonies were counted and their numbers were expressed as viable numbers of microorganisms in colony-forming units (cfu) per gram of fresh matter.

2. Statistical data

The statistical data used in this paper were cited from the CPD (Cooperative Promotion Department under Ministry of Agriculture and Cooperatives, Thailand) and OAE (Office of Agriculture Economics under Ministry of Agriculture and Cooperatives, Thailand), and were supplied through the courtesy of Mr. Hiroshi Nambu who is a JICA (Japan International Cooperation Agency) expert of OAE.

Results and discussion

1. Changes in the number of cattle head and the amount of raw milk production, demand and import during the period 1991–2000

The number of cattle and dairy cattle, the amount of raw milk production and demand, and the amount of milk products imported as well as the self-sufficiency ratio in raw milk production during the period 1991–2000 are shown in Table 1. These data were cited from the Agriculture Statistics of Thailand, OAE. Changes in the number of dairy cattle, amount of raw milk production and demand, and self- sufficiency ratio in raw milk production during the past 10 years are also shown in Fig. 1. The amount of raw milk demand in 1991 and 2000 was 256,000 and 597,000 t, respectively, with an increase of 2.3 times. The amount of raw milk production in 1991 and 1999 was 142,000 and 442,000 t, respectively, with an increase of 3.1 times during the past 9 years. However, the self-sufficiency ratio in raw milk production was low, about 50% of the demand, though it was 75–78% in 1998 and 1999, due to the financial crisis. On the other hand, the number of dairy cattle increased from about 48,000 to about 143,000 (increase of about 3.0 times) while the number of cattle increased from about

Table 1. Changes in the number of cattle and dairy cattle, and the amount of raw milk production, demand and import in Thailand during the period 1991–2000

Year	Cattle (head)	Dairy cattle (head) [A]	RMP[1)] (t) [B]	DRM[2)] (t) [C]	RMPC[3)] [B×1000/A]	SSR[4)] (%)	IMC[5)] (t)	IPM[6)] (t)
1991	105,766	47,775	142,253	256,278	2,978	55.6	69,282	–
1992	93,150	43,940	134,011	302,479	3,050	44.3	86,986	–
1993	126,267	55,751	157,288	362,807	2,820	43.4	77,152	–
1994	181,026	72,488	205,407	425,903	2,834	48.2	102,897	–
1995	230,061	99,456	307,229	542,832	3,089	56.6	121,471	–
1996	274,613	130,434	343,388	654,203	2,633	52.5	117,836	30,793
1997	288,856	126,136	385,728	668,370	3,058	57.7	142,559	48,591
1998	287,732	126,779	387,918	511,405	3,060	75.9	105,104	34,325
1999	328,008	139,456	442,304	573,637	3,172	77.1	107,122	31,985
2000	357,010	143,213	–	596,893	–	–	–	34,495

1): RMP, Raw milk production. 2): DRM, Demand of raw milk. 3): RMPC, Raw milk production ability (kg/head/lactation).
4): SSR, Self-sufficiency rate in milk [{1-(C-B)/C}× 100]. 5): IMC, Milk and cream imported.
6): IPM, Powder milk imported.

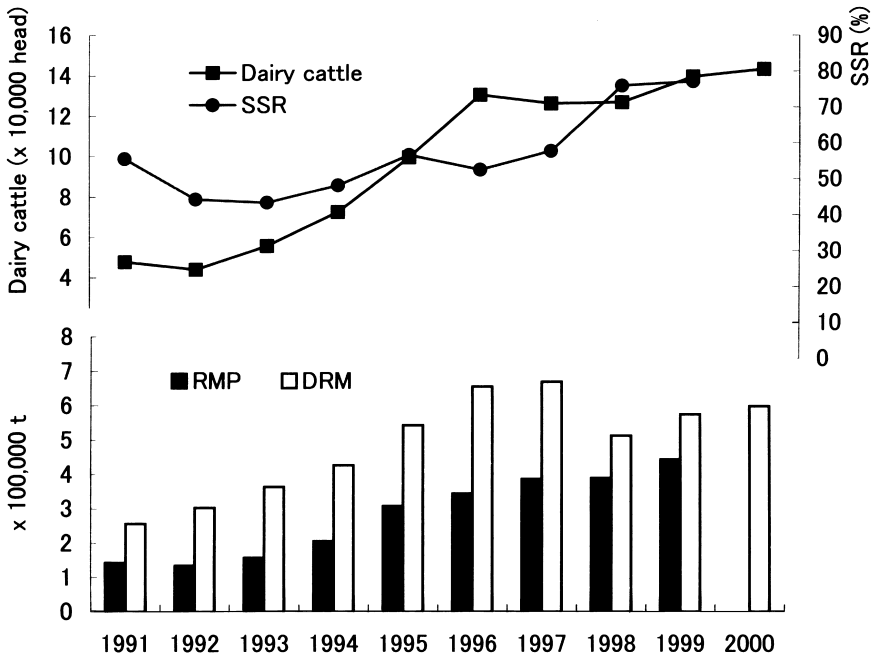

Fig. 1. Changes in RMP, DMP, SSR and number of dairy cattle in Thailand (1991–2000)
RMP: Quantity of raw milk production, DMP: Demand of raw milk,
SSR: Self-sufficiency ratio in raw milk.

106,000 to about 357,000 (increase of about 3.4 times). And the average raw milk production during the period 1991–1999 was 2,970 kg/head/lactation while during the period 1996–1999 it increased to 3,100 kg/head/lactation.

Although dairy farming in Thailand is not the main livestock industry, it is necessary to increase the number of dairy cattle because of the large demand for raw milk. The amount of raw milk production during the period 1991–2000 increased rapidly in proportion to the amount of raw milk demand as shown in Fig. 1. The increase in the amount of raw milk production was not caused by the increase of the ability of raw milk production which, on the average during the period 1991–1999, had remained almost constant (about 2,970 kg/head/lactation), but by the increase of the number of dairy cattle. The low ability of raw milk production is due to the technology related to the feeding and management of dairy cattle. In the case of the "Dairy farming development project in Thailand" (1993–1998) conducted by JICA, the improvement of conventional dairy farming technologies and technical training for feeding and management of dairy cattle were being emphasized. The model farm of the JICA project recorded a raw milk production of about 4,000–4,500 kg/head/lactation by feeding of Napiergrass silage as roughage throughout the year[8]. This quantity of milk was about 1.4–1.5 times higher than that of the average production in Thailand during the period 1991–1999. If the techniques developed by the JICA project could be disseminated all over the country, the lack of raw milk in Thailand may be alleviated. Namely, it appears that the preparation and feeding of good quality silage will prevail for future dairy farming in Thailand.

2. Changes in the number of cattle and dairy cattle, and in the amount of raw milk production in the regions during a 3-year period (1998–2000 and 1997–1999)

The number of cattle and dairy cattle, and the amount of raw milk production in North, Northeast, Central and South Thailand during a 3-year period (1998–2000 and 1997–1999) are shown in Table 2. These data were cited from the Agriculture Statistics of Thailand, OAE. The number of dairy cattle in Thailand increased by 5–6% over the former number per year during the period 1997–1999. Especially in Central Thailand, the ratio of increase was 5.4–5.9% while in Northeast Thailand it was 1.7–3.7%. The number of dairy cattle fed in Central Thailand, such as in Ratchaburi Province, Saraburi Province, Lop Buri Province, etc., accounted for 67.3% of the total number and for 69.3% of the raw milk production in Thailand. The ability of raw milk production in Central Thailand was 3,406 kg/head/lactation on the average. On the other hand, the number of dairy cattle and the amount of raw milk production in Northeast Thailand, such as in Khon Kaen Province, Udon Thani Province, etc., accounted for only 24.1% and 22.1% of

Table 2. Changes in the number of cattle and dairy cattle, and in raw milk production in the regions of Thailand during a 3-year period (1998–2000 and 1997–1999)

Region	Cattle (head)			Dairy cattle (head)			Raw milk production (t)			RMP[1)] (kg/head/day)			RMP[1)](kg/head/lactation)		
	1998	1999	2000	1997	1998	1999	1997	1998	1999	1997	1998	1999	1997	1998	1999
N-Thailand	22,410	25,344	27,561	8,133	9,472	10,482	26,345	31,522	35,166	8.67	9.12	9.19	3,239	3,328	3,355
Chiang Mai	9,421	11,012	12,369	3,789	4,369	4,890	13,621	16,104	18,102	9.85	10.10	10.14			
Sukhothai	2,538	2,818	3,149	692	1,015	1,160	2,173	3,322	3,815	8.61	8.97	9.01			
Phetchabun	3,105	2,963	2,888	1,157	1,118	1,111	3,369	3,375	3,484	7.98	8.27	8.59			
NE-Thailand	82,760	84,714	84,790	30,757	31,894	32,447	93,341	96,128	99,997	8.31	8.26	8.44	3,035	3,014	3,082
Khon Kaen	6,778	8,303	8,125	2,676	3,001	3,191	8,126	8,993	9,830	8.32	8.21	8.44			
Udon Thani	4,626	4,557	4,370	1,969	1,888	1,861	6,107	5,980	5,923	8.50	8.68	8.72			
Sakon Nakhon	4,030	3,845	3,634	1,599	1,442	1,300	4,161	3,957	4,147	7.13	7.52	8.74			
C-Thailand	212,093	222,699	232,954	84,083	89,031	93,852	284,667	302,968	321,845	9.28	9.32	9.40	3,386	3,403	3,429
Sara Buri	40,862	40,964	43,606	16,055	16,683	17,470	60,417	62,963	66,061	10.31	10.34	10.36			
Lop Buri	34,568	36,507	36,058	12,651	13,835	14,971	43,773	47,569	51,584	9.48	9.42	9.44			
Ratchaburi	61,957	66,835	70,378	26,035	27,610	28,800	81,913	88,885	93,136	8.62	8.82	8.86			
S-Thailand	5,991	6,508	6,705	2,070	2,177	2,485	6,080	6,499	7,507	8.05	8.18	8.28	2,937	2,985	3,021
Chumphon	1,696	2,372	2,424	651	762	945	2,149	2,531	3,142	9.05	9.10	9.11			
Patthalung	1,928	1,861	2,116	642	690	795	1,893	2,039	2,356	8.08	8.10	8.12			
Total (Ave.)	323,254	339,265	352,010	125,042	132,574	139,266	410,433	437,116	464,514	8.99	9.03	9.14	3,149	3,183	3,222

1): RMP, Raw milk production.

Table 3. Quantity of raw milk collected in the regions by the CPD during the period 1996-2000

Region	1996		1997		1998		1999		2000	
	QRM[1)]	Ratio[2)]	QRM[1)]	Ratio[2)]	QRM[1)]	Ratio[2)]	QRM[1)]	Ratio[2)]	QRM[1)]	Ratio[2)]
C-Thailand	498	25.4	836	31.8	873	32.0	1,001	31.0	1,211	32.3
W-Thailand	768	39.1	941	35.8	954	34.9	1,073	33.3	1,301	34.7
E-Thailand	191	9.7	227	8.6	266	9.7	319	9.9	309	8.2
NE-Thailand	320	16.3	411	15.6	382	14.0	495	15.3	555	14.8
N-Thailand	148	7.5	165	6.3	204	7.5	285	8.8.	297	8.0
S-Thailand	38	2.0	51	1.9	51	1.9	53	1.7	76	2.0
Whole	1,963	100.0	2,631	100.0	2,730	100.0	3,226	100.0	3,749	100.0

1): Quantity of raw milk collected (100 t). 2): Percentage against whole quantity.

those in Thailand, respectively. And the average quantity of raw milk production was only 3,044 kg/head/lactation, a value about 0.89 times that in Central Thailand. These trends are supported by the data of the CPD which operates 106 centers for raw milk collection in the whole country (Table 3) and which collects about 60% of the total raw milk produced in Thailand. Namely, the quantity of raw milk collected in Northeast Thailand accounted for only 14–16% of the amount of raw milk collected in the whole country while in Central Thailand, it accounted for 74–76% of the total (the area of Central Thailand in this Table was divided into Central, East and West Thailand).

The quantity of raw milk production in Northeast Thailand accounted for about 20% of the total in Thailand. The amount of raw milk production in Northeast Thailand was low, about 0.89 times that in Central Thailand for unknown reasons. However, it was suggested that dairy farming has become an important sector[9] in agriculture based on the collaborative research project titled: “Comprehensive studies on sustainable agriculture systems in Northeast Thailand” conducted by JIRCAS (Japan International Research Center for Agricultural Sciences). The increase of raw milk production in Northeast Thailand is also important. The development of good-quality roughage and feeding techniques should enable to alleviate the low level of raw milk production in Northeast Thailand.

3. Monthly changes in raw milk production during the period 1996–2000

Monthly changes in the amount of raw milk collected by the Center under CPD during the period 1996–2000 are shown in Table 4. The relative value of the quantity of raw milk collected each month against the maximal monthly quantity is shown in Fig. 2. It appears that the monthly quantity of raw milk collected by the CPD decreased in the middle of the dry season (January and February) and at the end of the rainy season (September and October). The large reduction in September may be due to the following reasons: 1. Bacterial contamination of raw milk associated with unsanitary conditions around the cowshed caused by rain. 2. Use of drugs to treat mastitis and cold whose incidence occurs frequently in the rainy season, resulting in the discontinuation of raw milk shipments. 3. The fact that September coincides with the drying period of lactation. These problems may be attributed to inadequate farm manage ment and the delay in the training in and dissemination of basic technologies. The reduction in the quantity of raw milk in February can be ascribed to the lack of good-quality roughages in the dry season. However, raw milk production increased in March and April in spite of the dry season due to the use of concentrates and TMR (total mixed

Table 4. Monthly quantity of raw milk collected by the CPD during the period 1996–2000

Year	Raw milk collected (100 t)												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
1996	168	165	160	164	170	169	162	158	154	153	158	182	1,962
1997	188	202	213	216	220	235	241	229	219	218	220	228	2,630
1998	229	202	232	228	241	240	231	224	214	211	226	240	2,730
1999	256	262	256	271	277	274	266	274	269	247	273	301	3,225
2000	320	314	316	319	338	317	309	298	298	289	313	320	3,750

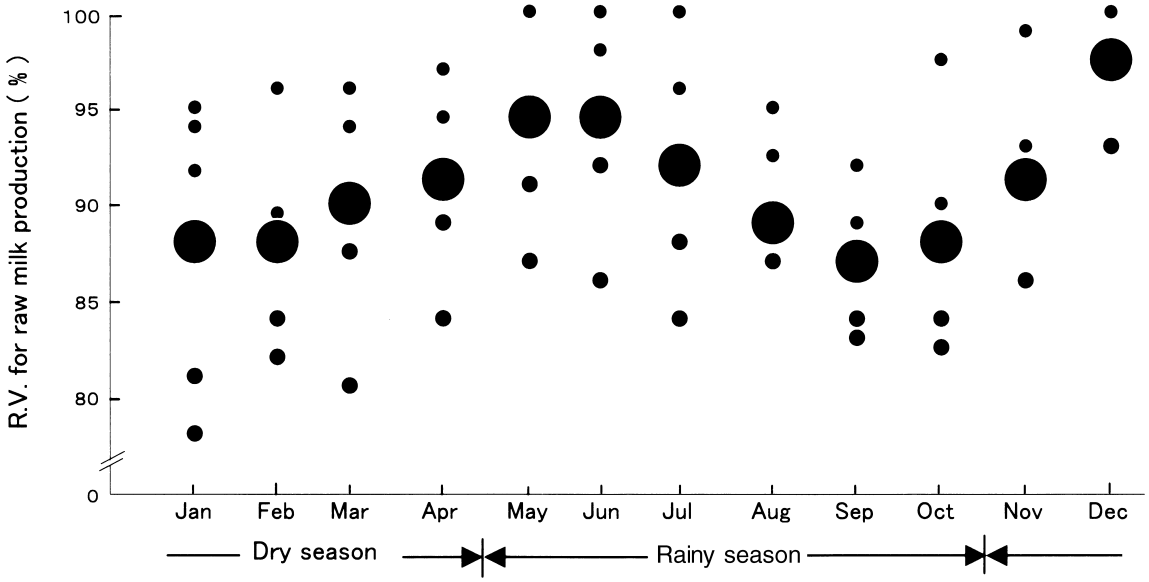

Fig. 2. Changes in the relative value of raw milk collected by the CPD during the period 1996–2000
Small ● : Relative value of the quantity of raw milk collected each year,
Large ● : Average for relative value of the quantity of raw milk collected each year.

ratio) silage, resulting in the increase of the cost of raw milk production in the dry season. The use of good quality silage throughout the year combined with the improvement of the conditions around the cowshed may enable to secure a stable and high production of raw milk at a low cost.

4. Common roughage for dairy cattle in Thailand and microbial characteristics of silage prepared in Thailand

For feeding cattle, dairy farmers in Central Thailand are commonly using fresh pasture crops such as Ruzi grass, Napiergrass, Para grass, Rhodes grass, etc., and fresh residues of baby corn after harvest, as well as rice straw in the dry season, together with concentrate feed. However, some advanced dairy farmers in Chon Buri Province and Kanchanaburi Province have formed an association and are collaborating in making silages from pasture crops and corn and /or TMR silage from a mixture of rice bran, cassava, agro-wastes from cotton seed, sesame seed oil, pineapple peel, etc., for feeding the animals throughout a year. Compared with average farm-

Table 5. Fermentation quality of grass silages prepared in Thailand

Sample[1)] No.	pH	Moisture content (%)	Count of microorganisms[2)] (cfu/g)				
			TVC	LAB	Yeast	Mold	Entero B.
SS1	7.66	41.9	6.0×10^6	$<10^1$	3.0×10^4	1.3×10^4	3.0×10^3
SS2	7.71	60.4	5.0×10^6	$<10^1$	6.0×10^4	2.0×10^4	9.0×10^3
SS3	7.13	47.9	2.6×10^7	7.0×10^5	1.1×10^5	6.0×10^4	6.2×10^5
SS4	4.35	48.8	9.0×10^4	2.0×10^6	4.0×10^5	2.0×10^4	1.3×10^3
CS1	3.82	78.0	5.1×10^6	3.3×10^6	5.4×10^4	$<10^1$	$<10^1$
CS2	3.75	83.0	4.0×10^6	1.7×10^8	4.9×10^4	$<10^1$	$<10^1$
KS1	5.10	28.1	4.6×10^7	2.8×10^7	2.0×10^2	1.1×10^3	$<10^1$
KS2	4.04	30.0	1.9×10^7	4.6×10^7	$>10^1$	$<10^1$	$<10^1$

1): SS1, Ruzi grass silage from the surface of bunker No.1 in Sara Buri Province; SS2, from inside of bunker No.1, as in SS1; SS3, from the surface of bunker No.2 in Sara Buri Province; SS4, from inside of bunker No.2, as in SS3; CS1, Corn silage from the surface of bagged silo in Chonburi Province; CS2, from inside of bagged silo as in CS1; KS1, Corn silage in Khon Kaen Province; KS2, Corn silage with the addition of 5% molasses in Khon Kaen Province.
2): TVC, Bacteria counted in nutrient agar medium; LAB, Lactic acid bacteria counted in Lactobacilli MRS agar medium; Yeast and Mold, counted in potato dextrose agar medium; Entero B., Enterobacteria counted in Violet Red Bile Agar with lactose.

ers, they apply advanced techniques of feeding management and an average raw milk production of more than 4,500 kg/head/lactation could be obtained. This quantity was similar to that recorded in the JICA project and they obtained a stable large income. This example has increased the interest of dairy farmers in silage-making.

Generally, tropical pasture crops contain a small amount of sugars[3] and can not be used for the preparation of good-quality silage. Therefore, molasses are added as a sugar source. Ruzi grass silages shown in Table 5, i.e. samples SS1-SS4 prepared in Saraburi Province, were put in bunkers (width 6 m, length 10 m, height 2 m) with about 2% molasses and without drying of the pasture crop. Samples SS1 and SS3 were collected from the surface of silage in bunkers No. 1 and No. 2, respectively. Samples SS2 and SS4 were collected from inside of the silage (at a depth of 50–60 cm from the surface) in bunkers No. 1 and No. 2, respectively. The quality of silages from bunker No. 1 was very poor, whereas the quality of the silage from inside of bunker No. 2 (SS4) was good (pH = 4.35) and the quality of the silage from the surface of the same bunker was very poor (pH = 7.13). The addition of molasses to pasture crops should vary, which suggests that the basic techniques used for the preparation of good quality silage have not been widely adopted in Thailand, due to the lack of experience in silage-making among dairy farmers.

These 4 silages contained a relatively low number of LAB and high number of aerobic bacteria and entero-bacteria compared with the grass silage prepared in Japan. The number of clostridia was also low in the silage prepared in Thailand. Samples CS1-CS2 and KS1-KS2 consisted of corn silage prepared in bagged silos for transportation in Chonburi Province and Khon Kaen Province, respectively. These silages showed a low pH, high number of LAB and relatively low number of other microorganisms.

The microbial flora of these silages with a large number of yeasts and bacteria but few LAB, etc. was considerably different from that of the silages prepared in Japan. The inhibition of the growth of yeasts, aerobic bacteria and entero-bacteria (coliform bacteria: CFB) in the silages in Thailand is important while the inhibition of the growth of butyric acid bacteria (BAB) is essential for making good-quality silage in Japan[6,7]. This is because yeasts utilize lactic acid as a carbon source for growth under aerobic conditions (after opening of silo), change the pH value of silage to neutral, and promote the growth of aerobic bacteria. This phenomenon is referred to as "aerobic deterioration"[2] and results in the loss of nutrients in silage and reduction of the time required for keeping the silage quality, which are referred to as "shortening of bank life". It is thus obvious that the silages prepared in Thailand are not always of good quality, due to natural silage fermentation under adverse conditions. On the other hand, the use of LAB which are adapted to the tropical climate and the natural environment of Thailand, and inhibit the growth of yeasts and CFB could be more suitable. However, LAB strains as a silage additive for tropical silage-making[4] are not available. Therefore, a convenient and easy model of silage fermentation system, which is a modification of the "pouch method" developed for the screening of LAB strains adapted to the Japanese climate and natural conditions for silage-making[6], is being studied by the author's research group. This system is a kind of solid mixed-culture consisting of LAB, yeasts and CFB under anaerobic conditions. In the near future, LAB strains for silage-making in Thailand will be developed as a tropical silage additive.

Conclusion

1. Raw milk production in Thailand increased by about 3.1 times during the period 1991–1999. However, the self-sufficiency ratio in raw milk production still remains low.
2. Recent average raw milk production in Thailand is about 3,000 kg/head/lactation. However, this amount could be increased to about 4,000–4,500 kg/head, reaching the level recorded in the JICA project. Such an objective could be attained by the feeding of good-quality silage.
3. The central part of Thailand is the main area for raw milk production in Thailand, accounting for about 70% of the total production, while Northeast Thailand accounted for only 20%.
4. Monthly amount of raw milk production decreased in the middle of the dry season (January and February) and at the end of the rainy season (September to October), due to the lack of good-quality roughage, treatment of mastitis and unfavorable environment around the cow-shed associated with rain, respectively.
5. Roughages commonly used in Thailand consist of tropical pasture crops, rice straw and some agro-wastes. However, advanced farmer groups are using corn silage and/or TMR silage throughout a year for feeding the animals and they have achieved a high raw milk production.
6. It was recognized that the microbial flora of the silages prepared in Thailand generally contained a low amount of LAB and high amounts of yeasts, aerobic bacteria and CFB.
7. It was eventually suggested that LAB suitable for the making of good-quality silage in Thailand should be selected and used as an additive to enhance lactation in

dairy cows.

References

1. Cai, Y. et al. (1998) Influence of *Lactobacillus* spp. from an inoculant and of *Weissella* and *Leuconostoc* spp. from forage crops on silage fermentation. *Appl. Environ. Microbiol*., **64** (8) 2982–2987.
2. Kitamoto, H. K. et al. (1999) Prevention of aerobic spoilage of maize silage by a genetically modified killer yeast, *Kluyveromyces lactis*, defective in the ability to grow on lactic acid. *Appl. Environ. Microbiol*., **65** (10) 4697–4700.
3. McDonald, P., Henderson, A. R. & Heron, S. J. E. (1990) Crops for silage. *In* The Biochemistry of Silage, 2nd Ed. Chalconbe publications, England, 19–47.
4. Ohmomo, S. et al. (1995) Screening of lactic acid bacteria suitable for silage-making in tropical regions. *JARQ*, **29** (4) 251–256.
5. Ranong, V. N. (1999) The financial crisis and the livestock sector in Thailand. *In* Proceedings of the workshop on the implications of the Asian economic crisis for the livestock industry. Bangkok, 175–202.
6. Tanaka, O. & Ohmomo, S. (1995) A simple method of laboratory silage fermentation by using a plastic pouch for packaging. *Grassl. Sci*., **41** (1) 55–59 [In Japanese with English summary].
7. Tanaka, O. & Ohmomo, S. (1998) Lactic acid productivity of the selected strains of the genus *Lactobacillus* in laboratory-scale silages. *Grassl. Sci*., **43** (4) 374–379.
8. Technical Cooperation Division of Agriculture Development Cooperation Department (1998) Final evaluation report on the dairy farming development project in the central region of the Kingdom of Thailand. Japan International Cooperation Agency, Tokyo, pp.136.
9. Udchachon, S., Sumamal, W. & Kawashima, T. (1996) Feed and feeding management for small dairy farms in the northeast of Thailand. *In* Proceedings of the satellite symposium of the 8th AAAP congress in Tsukuba Science City (Oct., 1996), National Institute of Animal Industry, Tsukuba, Japan, 31–40.