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REPORT OF RESEARCH PROJECTS DELIVERABLES

2014 - 2015

Contents

Part III 2015 SDDDC PPS Dutch projects

Part I

2014 SDDDC Chinese projects

Chapter 1 2014-R1 QC in chain - SCC & UHT

Impacts of somatic cell counts and storage temperature on UHT Milk Proteolysis and the milk fat globule during Storage

1.1 About Principle Investigator

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Short Curriculum Vitae

Education

09/ 2004 –07/2009	China Agricultural University, Master and Doctor Science in Dairy Science
09/2000 – 07/2004	China Agricultural University, Bachelor Science in Food Science & Nutritional Engineering
09/ 2011 –02/2012	visiting scholar in Cornell University

Main research area(s):

1. The molecular mechanisms of milk source active substances' function

Aiming at lactoferrin, milk fat globule membrane protein and other milk source active substances as the research objects, elucidated their interactions with the receptor and the start-up process of intracellular signal transduction and clarified their promotion of bone growth and the molecular mechanisms of neural development.

2. Investigate the association between human milk composition and infant gut health

Breast milk and infant feces samples are collected and analyzed the composition of immune proteins and oligosaccharides in the breast milk by means of proteomics and glycomics. High-through put sequencing technology was used to study the structure and evolution characteristics of infants' intestinal flora, then elucidate the relationship between breast milk composition and infant intestinal health.

1.2 Background

UHT treatment of milk is a heating process at very high temperatures for short holding times, which renders the milk commercially sterile and gives a product with along shelf life at ambient temperatures. UHT treatments can cause sufficient reduction of micro-organisms, while doing minimal teat damage to milk constituens, such as vitamins and whey proteins.

Although reached the standard of the commercial asepsis, UHT milk is not absolutely safe still. During the process, most bacteria are inactivated but heat-stable enzymes of native or bacterial origin can survive and cause serious defects during storage of the milk. The quality of raw milk, processing technology and storage conditions are some of the major limiting factors for the shelf life of UHT milk, which can affect the product quality during storage. Milk somatic cell count (SCC) and stage of lactation have been shown to affect the composition of raw milk. As far as we know, mastitis milk (milk with high SCC) subjected to UHT treatment is more susceptible to some quality problems than normal milk. Besides, the storage condition is also a key factor for keeping the good quality. Many reactions in UHT milk such as lipid oxidation may be affected by the temperature during storage.

Proteolysis in UHT milk can cause the development of bitter flavor and leads to an increase in viscosity, with eventual formation of a gel during storage, which is a major factor limiting its shelf-life and market potential (Datta & Deeth, 2003).

In this study, the influence of raw milk quality of somatic cell counts(SCC) and UHT storage temperature on the proteolysis and fat hydrolysis degree of UHT milk were investigated during storage at 20,30,40temperature.

1.3. Milk samples and UHT processing

Bulk milk samples with different somatic cell count were obtained from a local dairy enterprise. Grading samples according to SCC, all milk was processed by indirect heating at 147 °C for 4s in UHT plant, and packaged in sterile 225mL tetra container. All experimental batches were prepared on the same day and sampled for analysis after 0, 30, 60, 90, 120, 150 and 180d storage at 20,30,40°C，respectively.

Table 1-1 Information of raw milk

Somatic cell division		total bacterial count ($\times 10^4$ cfu/mL)	SCC ($\times 10^4$ cfu/mL)	titratable acidity (/°T)	protein(g/100g)	fat(g/100g)	pH	psychrotrophic bacteria count($\times 10^4$ cfu/mL)	batch
LSCC ($\times 10^4$ cfu/mL)	30	25.0	34.7	12.9	3.07	3.83	6.40	2.9	1C20150319AB05f
		21.4	31.6	13.3	3.06	3.74	6.64	4.0	1C20150319AB04c
		10.7	30.9	12.4	3.07	3.83	6.40	5.2	1C20150320AB03e
HSCC ($\times 10^4$ cfu/mL)	80	24.0	82.7	13.3	3.04	3.71	6.62	2.0	1C20150320AB07e
		24.0	82.7	13.3	3.04	3.71	6.62	2.0	1C20150320AB08b
		24.0	82.7	13.3	3.04	3.71	6.62	2.0	1C20150320AB06c

1.4 Results and conclusions

1.4.1 Enzyme activity

1.4.1.1 Plasmin and plasminogen activity

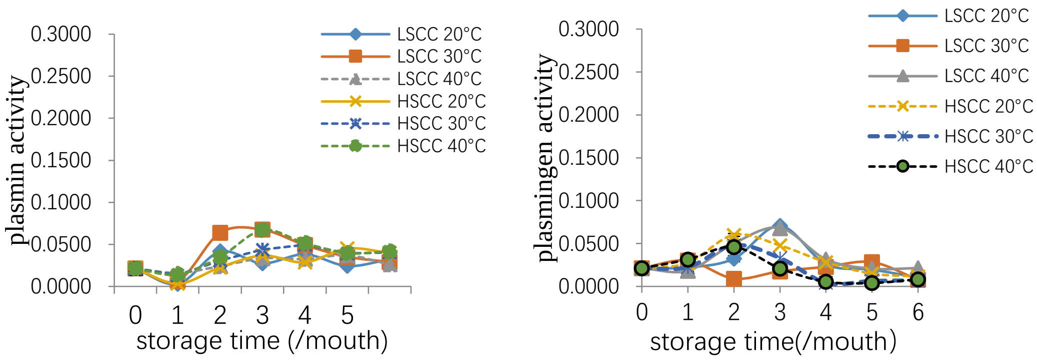


Fig. 1-1 Changes in plasmin and plasminogen activity of different SCC UHT milk during storage period

The changes in plasmin and plasminogen activity of different SCC UHT milk during storage period in shown in Fig.1-1. Milk plasmin and plasminogen activity of both SCC level milk was constant between 0.0 and 0.0700U/mL during the first 6 mouths of storage. We can speculate that raw milk after UHT sterilization, milk PL has basically complete deactivation.

1.4.1.2 Lipase activity

Table 1-2 Changes of lipase activity of UHT milk during storage

Storage month	LSCC temperature(/°C)			HSCC temperature(/°C)		
	20	30	40	20	30	40
1	0.08±0.03^{Ac}	0.06±0.05^{Ab}	0.06±0.04^{Aa}	0.06±0.02^{Ab}	0.06±0.03^{Aab}	0.02±0.00^{Aa}
2	0.06±0.01^{Abc}	0.05±0.03^{Aab}	0.07±0.04^{Aa}	0.08±0.01^{Ab}	0.08±0.01^{Ab}	0.07±0.00^{Abc}
3	0.03±0.01^{Aa}	0.06±0.01^{Bb}	0.03±0.01^{Aa}	0.03±0.01^{Aa}	0.06±0.00^{Bab}	0.04±0.03^{ABabc}
4	0.06±0.01^{Abc}	0.07±0.00^{Ab}	0.04±0.02^{Aa}	0.06±0.01^{Ab}	0.04±0.02^{Aa}	0.08±0.04^{Ac}
5	0.04±0.02^{Bab}	0.02±0.00^{Aa}	0.04±0.00^{Ba}	0.07±0.01^{Cb}	0.04±0.00^{Ba}	0.04±0.01^{Babc}
6	0.05±0.01^{Babc}	0.06±0.01^{Bab}	0.05±0.01^{ABa}	0.06±0.01^{Bb}	0.06±0.01^{Bab}	0.04±0.00^{Aab}

^{a} results are shown as average ± standard deviation of three replicates.

There's no pronounced change of lipase activity was found during storage period for 6 months. Besides, no pronounced rule was found with the raw milk SCC and the storage temperature.

1.4.2 Viscosity

The changes in viscosity of the six UHT milk types during storage are represented in Table 1-3. All samples initially underwent a slight decrease in viscosity, followed by a long delay, during which little change occurred. Milk of both SCC level milk did not change significantly during the applied storage period which was constant between 2.0 and 2.4 mPa s., thus there is no significant different between different somatic cell count and storage temperature.

Table 1-3 Changes in viscosity of different SCC UHT milk during storage period

Storage month	LSCC temperature(/°C)			HSCC temperature(/°C)		
	20	30	40	20	30	40
0	2.26±0.01^{Ba}	2.26±0.01^{Ca}	2.26±0.01^{Ca}	2.36±0.04^{Cb}	2.36±0.04^{Bb}	2.36±0.04^{Db}
1	2.13±0.03^{Ad}	2.06±0.01^{Abc}	2.02±0.01^{Aa}	2.09±0.01^{Ac}	2.08±0.01^{ABc}	2.04±0.01^{ABab}
2	2.30±0.08^{Ba}	2.22±0.02^{BCa}	2.26±0.03^{Ca}	2.30±0.08^{BCa}	2.31±0.13^{Ba}	2.36±0.04^{Da}
3	2.15±0.01^{Af}	2.05±0.05^{Abc}	2.00±0.02^{Aab}	2.11±0.00^{Ade}	2.06±0.02^{Acd}	1.98±0.04^{Aa}
4	2.33±0.05^{Bb}	2.23±0.02^{BCab}	2.18±0.02^{Bab}	2.26±0.05^{BCb}	2.26±0.17^{BCDab}	2.11±0.06^{BCa}
5	2.36±0.01^{Bb}	2.26±0.01^{Cab}	2.16±0.02^{Ba}	2.19±0.15^{ABa}	2.20±0.01^{ABCa}	2.20±0.03^{Ca}
6	2.33±0.11^{Bb}	2.21±0.02^{Ba}	2.15±0.07^{Ca}	2.32±0.03^{BCb}	2.15±0.03^{ABa}	2.10±0.02^{BCa}

Note: Data was expressed as means±sd, n=3, mPa.s
abc means on the same row without a common subscript are signicantly different (P<0.05).
ABC means on the same column without a common subscript are signicantly different (P<0.05).

An observed increase in viscosity with the onset of gelation has been reported previously by Kohlmann et al. (1991) and Kelly and Foley (1997) who proved that Gel aging phenomenon is associated with PL activity in milk. The results of this experiment also confirmed this view, may be due to UHT milk PL substantially completely inactivated, all UHT milk during storage have not gelled aging phenomenon.

1.4.3 pH and Titratable acidity (°T)

pH values of all UHT milk have always been decreasing in the 6 months' storage period. Storage temperature has caused significant influence (P>0.05), which means the higher storage temperature could result in the lower pH value. Raw milk SCC made obvious difference. In the chart we can see that the LSCC group' pH is lower than HSCC ones in the same month.

Table 1-4 Changes of pH of UHT milk during storage

Storage month	LSCC temperature(/°C)			HSCC temperature(/°C)		
	20	30	40	20	30	40
1	6.78±0.01^{Aa}	6.75±0.00^{Ba}	6.71±0.00^{Ca}	6.78±0.02^{Aa}	6.76±0.03^{ABa}	6.72±0.01^{Ca}
2	6.65±0.01^{Ac}	6.61±0.00^{Bb}	6.52±0.02^{Db}	6.65±0.02^{Ab}	6.62±0.01^{Bb}	6.54±0.01^{Cb}
3	6.59±0.01^{Be}	6.55±0.01^{Cc}	6.40±0.01^{Ec}	6.63±0.01^{Ac}	6.56±0.01^{Cc}	6.43±0.03^{Dc}
4	6.71±0.01^{Bb}	6.62±0.01^{Cb}	6.42±0.03^{Dc}	6.67±0.01^{Ab}	6.63±0.01^{Cb}	6.41±0.01^{Dc}
5	6.53±0.01^{Bf}	6.45±0.01^{De}	6.24±0.03^{Fe}	6.57±0.01^{Ad}	6.48±0.01^{Ce}	6.29±0.01^{Ee}
6	6.61±0.01^{Ad}	6.51±0.01^{Bd}	6.29±0.02^{Cd}	6.62±0.02^{Ac}	6.53±0.01^{Bd}	6.30±0.02^{Cd}

Titratable acidity of all UHT milk have always been increasing as the month went on. Storage temperature has caused significant influence (P>0.05), showing that UHT milk storaged at higher temperature had higher titratable acidity. However, the raw milk SCC made no obvious difference to the titratable acidity (P>0.05).

Table 1-5 Changes of titratable acidity of UHT milk during storage

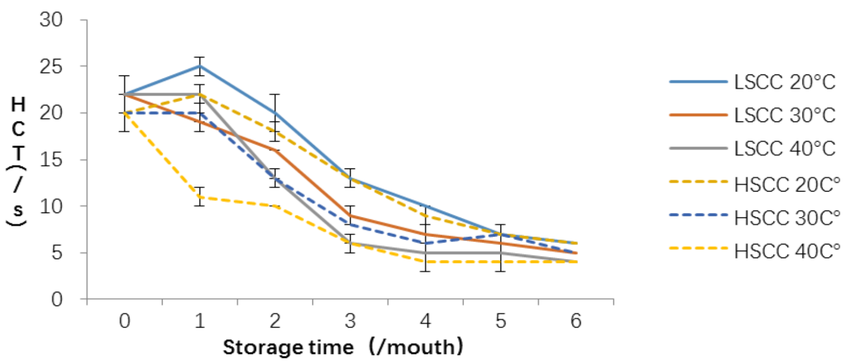
Storage month	LSCC temperature(/°C)			HSCC temperature(/°C)		
	20	30	40	20	30	40
1	15.62±0.06^{Aa}	15.42±0.30^{Aa}	15.55±0.57^{Aa}	16.00±0.22^{ABa}	15.97±0.29^{ABa}	16.26±0.10^{Ba}
2	17.06±0.31^{Ab}	17.33±0.15^{ABb}	18.76±0.49^{Cb}	17.16±0.25^{Ab}	17.71±0.06^{Bb}	19.48±0.25^{Db}
3	17.28±0.27^{Abc}	18.41±0.45^{Bd}	20.39±0.35^{Cc}	17.48±0.30^{Abc}	18.11±0.21^{Bbc}	20.99±0.40^{Cc}
4	18.52±0.26^{Ad}	19.77±0.40^{BCe}	22.28±0.56^{Dd}	19.05±0.56^{ABd}	20.06±0.44^{Ce}	23.39±0.32^{Ede}
5	17.81±0.27^{ABc}	18.92±0.10^{Cd}	22.61±0.67^{Dd}	17.64±0.50^{Abc}	18.38±0.21^{BCc}	22.75±0.27^{Dd}
6	17.29±0.45^{Abc}	17.89±0.19^{ABc}	22.49±0.08^{Dd}	18.16±0.38^{Bc}	19.92±0.12^{Cd}	23.90±0.75^{Ee}

Note: Data was expressed as means ± sd, n=3, °T
abc means on the same row without a common subscript are significantly different (*P*<0.05).
ABC means on the same column without a common subscript are significantly different (*P*<0.05)

1.4.4 Heat stability

Heat stability (Heat coagulation time, HCT) is described by the start coagulation time milk at 140 °C. The development in Heat stability of the six UHT milk types during storage is shown in Fig. 1-2. Heat stability of all milk samples decreased during storage. The decrease was more significant in the milk store in 40 °C, then 30 °C, and HSCC milk shown more pronounced decrease than LSCC milk.

Fig. 1-2 Changes in HCT of different SCC UHT milk during storage



1.4.5 Nitrogen distribution of milk

Changes in the degree of hydrolysis true protein and casein of different somatic scores in different storage temperature during the applied storage peiod is shown in Table 1-6 and 1-7.

Table 1-6 Changes in NPN/TN of different SCC UHT milk during storage

Storage Time (/month)	LSCC			HSCC		
	Storage Temperature(/°C)			Storage Temperature(/°C)		
	20	30	40	20	30	40
0	6.26±0.08^{BCa}	6.26±0.08^{Aa}	6.26±0.08^{Aa}	6.10±0.12^{Aa}	6.10±0.12^{ABa}	6.10±0.12^{Ba}
1	6.12±0.18^{ABCa}	6.51±0.17^{ABc}	6.75±0.05^{ABc}	6.15±0.16^{Ab}	5.71±0.31^{Aa}	6.56±0.03^{Ac}
2	5.49±0.26^{Aa}	6.12±0.10^{Aa}	7.09±0.09^{ABd}	6.75±0.13^{Ac}	6.58±0.29^{Bc}	6.81±0.12^{Ccd}
3	6.49±0.07^{BCab}	6.34±0.15^{ABa}	6.81±0.29^{ABbc}	6.71±0.27^{Aab}	6.62±0.11^{Bab}	7.09±0.22^{Cc}
4	5.94±0.37^{ABa}	6.77±0.18^{Bbc}	7.49±0.34^{BCcd}	6.51±0.45^{Aab}	7.13±0.42^{Cbcd}	7.66±0.26^{Dd}
5	7.35±0.26^{Da}	8.27±0.40^{Cab}	8.30±0.41^{CDab}	7.66±0.34^{Bab}	8.01±0.17^{Dab}	8.85±0.35^{Db}
6	6.75±0.67^{CDa}	7.86±0.35^{Cb}	9.20±0.35^{Dc}	7.43±0.47^{Bab}	8.15±0.30^{Db}	9.48±0.07^{Dc}

Note: Data was expressed as means ± sd, n=3
abc means on the same row without a common subscript are significantly different (*P*<0.05).
ABC means on the same column without a common subscript are significantly different (*P*<0.05)

NPN/TN increase in general, the change is most obvious under 40 ° C. Initial values of HSCC was slightly lower than those of LSCC, but from storage for two months, under different storage temperature, NPN/TN are higher than that of LSCC, suggesting HSCC samples protein hydrolyzed more seriously.

Table 1-7 Changes in NCN/TN of different SCC UHT milk during storage

Storage Time (/month)	LSCC			HSCC		
	Storage Temperature(/°C)			Storage Temperature(/°C)		
	20	30	40	20	30	40
0	9.67±0.15^{Aa}	9.67±0.15 ^{Aa}	9.67±0.15 ^{Aa}	9.85±0.22^{Aa}	9.85±0.22^{Aa}	9.85±0.22^{Aa}
1	10.93±0.58^{Aa}	11.14±0.23^{Bc}	11.21±0.63^{Bc}	10.57±0.38^{Ab}	10.38±0.29^{Aa}	10.30±0.64^{Ac}
2	13.03±0.11^{Babc}	13.19±0.21^{Cabc}	14.34±0.68^{Cc}	12.28±0.09^{Ba}	12.75±0.29^{Bab}	13.77±0.17^{Bbc}
3	12.97±0.21^{Ba}	13.40±0.31^{Cab}	14.74±0.89^{Cb}	12.80±0.80^{BCa}	14.31±0.63^{Cab}	16.51±0.47^{Cc}
4	13.96±0.79^{Bab}	13.25±0.17^{Ca}	15.27±0.93^{Cab}	14.00±0.12^{CDab}	14.96±0.63^{Cab}	15.92±0.47^{Cb}
5	13.90±0.50^{Ba}	14.89±0.19^{Db}	17.58±0.46^{Dc}	14.49±0.25^{Dab}	14.99±0.25^{Cb}	18.05±0.05^{Dc}
6	14.06±0.57^{Ba}	15.19±0.52^{Da}	17.52±0.12^{Db}	14.58±0.61^{Da}	15.16±0.66^{Ca}	18.11±0.83^{Db}

Note: Data was expressed as means ± sd, n=3
abc means on the same row without a common subscript are significantly different (*P*<0.05).
ABC means on the same column without a common subscript are significantly different (*P*<0.05)

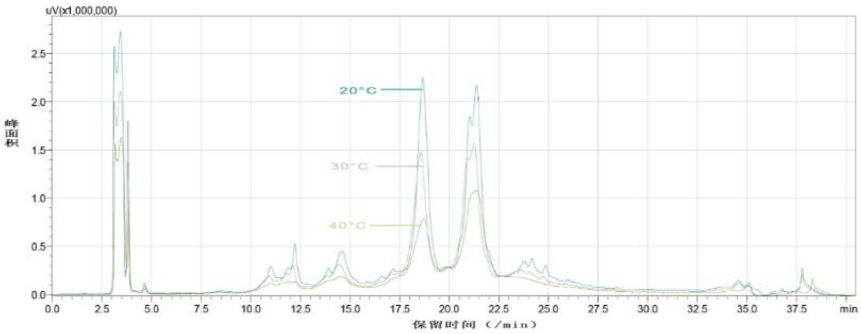
The development in NCN/TN of all milk sample (Table 1-7) showed a rapid increase between 0 and 3 months' storage and more slightly increase between 3 and 6 mouths storage. The greatest increase in NCN/TN was observed for the HSCC sample which store in 40°C.The increase was more significant in the milk store in 40 °C, then 30 °C, and HSCC milk shown more pronounced increase than LSCC milk.

There was no significance difference in NCN/TN between two SCC group under all storage temperature, indicating SCC has no impact on casein hydrolyzation for the moment.

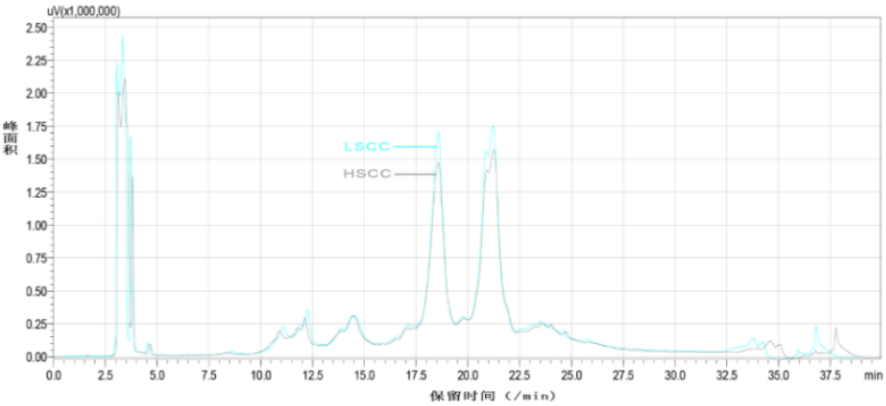
1.4.6 RP-HPLC results of milk

In Fig.1-3 (a) a comparison of the protein profiles of LSCC under different storage temperature after 2 months. Higher storage temperature leads to greater level of casein hydrolyzation

A comparison of different SCC group under 30°C after 2 month is shown in Fig.1-3(b)，At the same storage temperature, high somatic cell group degree of hydrolysis of casein is more serious than the low somatic cell group.



(a)



(b)

Fig. 1-3 Comparison of chromatograms of LSCC under different storage temperature after 2 month(a) Comparison of chromatograms of different SCC group under 30°C after 2 month(b)

The caseins that have been hydrolyzed are mainly β and κ-casein,αS1, αS2-casein also hydrolyzed slightly under 40 °C,LSCC showed lower level of β and κ-casein hydrolyzation than HSCC，SCC has a significant effect on β and κ-casein hydrolyzation.

After 6 months' storage, the b-casein peak decreased the most, followed by a slight decrease in aS1-casein and b-casein A2. The peak of b-casein A1 disappeared almost completely after 4 mouths storage, along with a large decrease in the aS1-caseinpeak. After 5 mouths storage, no intact aS1-casein with 9 phosphorylations(P) and b-casein A1 was present in the UV chromatogram (data not shown). Over the storage period, the k-casein peaks seemed to disappear, but developed similarly in both milk types, ruling out proteolysis as a cause for this change in k-casein profile. Instead, the disappearance can be attributed to a broadening of the peaks due to modifications of the proteins, likely by the Maillard reactions induced by the heat treatment (Gaucher, Mollé, Gagnaire, & Gaucheron, 2008).

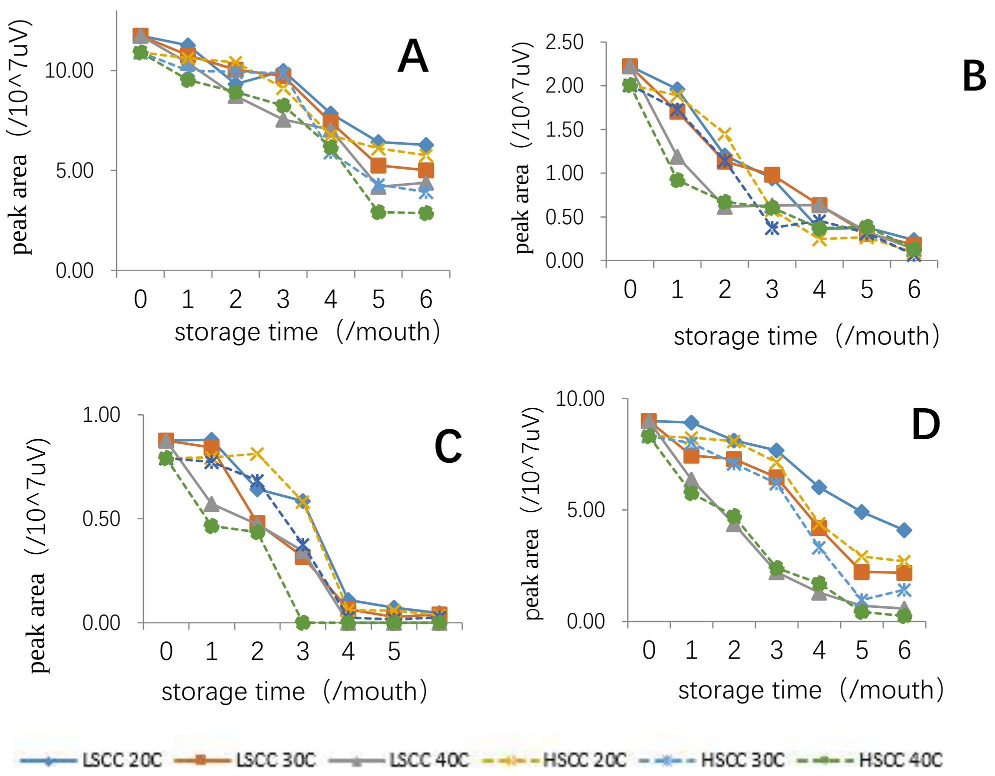


Fig. 1-4 Changes in β-casein (A)、κ-casein (B)、αS2-casein (C)and αS1-casein (D)of different SCC UHT milk during storage

1.4.7 Color difference and Diameter

Color difference and diameter results are shown in Fig.1-5.

The lightness of all UHT milk have been rise first and then fall along with the storage period. The value reached peak in month 4, and then decreased slowly.

Storage temperature has caused significant influence (P>0.05), which means the higher storage temperature could result in the lower L value. According to the result, those UHT milk storaged under 40°C had the darkest color. However, the raw milk SCC made no obvious difference to the lightness of UHT milk (P>0.05).

The color difference value in green/red axis of all UHT milk have always been increasing during the 6 month, meaning all groups of milk seemed more red from month to month. The raw milk SCC made no obvious difference to the lightness of UHT milk (P>0.05).

Storage temperature has caused significant influence (P>0.05), which means the higher storage temperature could result in the higher a value.

Storage temperature has caused significant influence on the color in blue/yellow axis (P>0.05). The storage condition of 40°Cmay cause the color changed to yellow significantly. This value of UHT milk under 30°Crises slowly, whereas those under 20°C almost kept at a constant level. Overall, the higher storage temperature could result in the higher b-value.

Nevertheless, raw milk SCC made no obvious difference to the lightness of UHT milk (P>0.05).

Fat globule size of UHT milk shad obvious increased from the second month of storage period (P<0.05) and no significant change appeared from then on. As to the difference caused by storage temperature, no pronounced rule was found corresponding to it. Consequently, the UHT milk fat globule diameter didn't increased dramatically as the temperature raised to 40°C. The particle size of LSCC group is larger than HSCC ones in the same month (P<0.05).

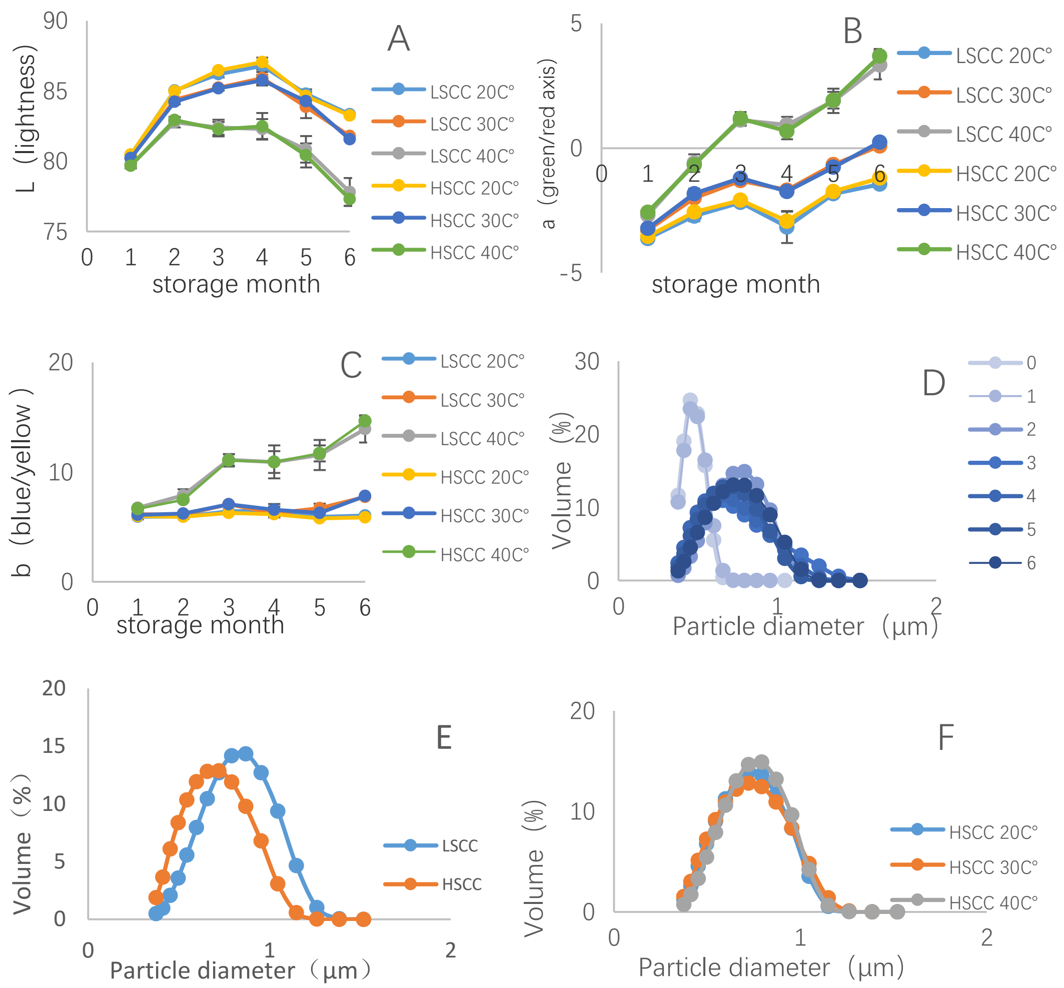
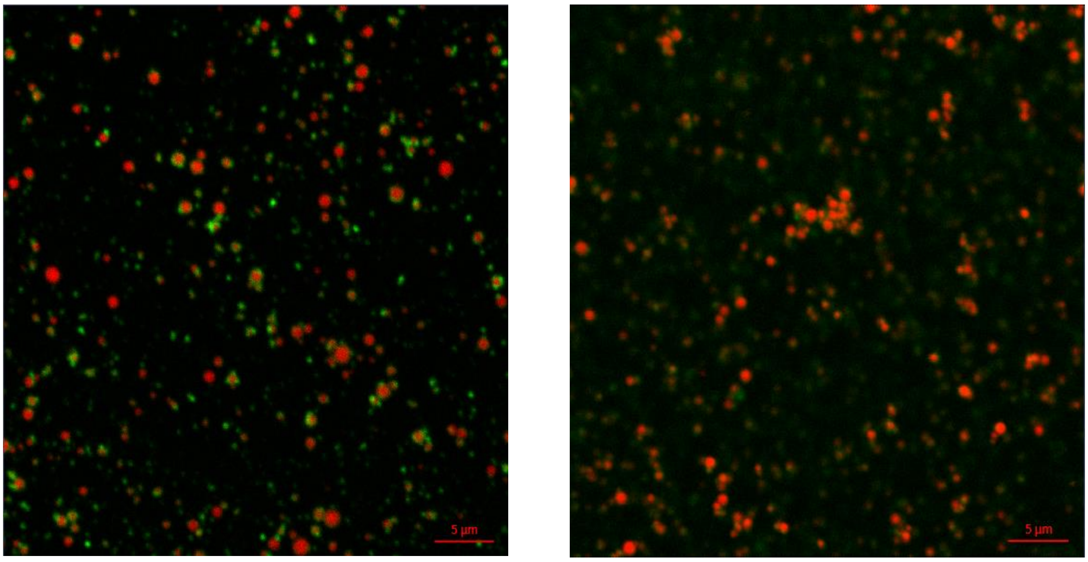


Fig. 1-5 Color difference in lightness(A)green/red axis(B) and blue/yellow axis(C)of UHT milk during storage, Particle diameter of HSCC under 40°Cin six months(D)、The particle diameter distribution of UHT milk under 40°C at 5th mon(E)and the particle diameter distribution of HSCC milk at 5th mon(F)

The Nile red stained fat appears red and the fast green FCF stained protein appears green in these images. AFG means the aggregates of fat globules and the scale bars are 10μm in length. The CLSM images show that the majority of fat globule in the UHT milk before storage are separate and most of these MFG appear to contact the protein tightly. While after 10 months of storage, the fat globules have aggregate and the reduction of protein could also be observed.



A B

Fig. 1-6 Stained MFG of LSCC UHT milk at the beginning of (A) and Stained MFG of LSCC UHT milk after 10 months(B)

1.4.8 ζ-potential

Apparent zeta-potential of all UHT milk fat globule have been rise first and then fall along with the storage period. The value reached peak in month 3, and dropped to its lowest level.

Neither the raw milk SCC nor the storage temperature caused significant influence (P<0.05).

Table 1-8 Changes of Apparent zeta-potential of milk fat globules of UHT milk during storage

Storage month	LSCC temperature(/°C)			HSCC temperature(/°C)		
	20	30	40	20	30	40
1	-21.33±3.13^{Aa}	-20.34±4.05^{Aab}	-19.61±2.51^{Aa}	-20.42±3.24^{Aa}	-20.48±2.26^{Aab}	-16.38±1.66^{Ab}
2	-17.92±0.16^{ABbc}	-18.93±0.64^{Aab}	-18.27±0.50^{ABab}	-18.15±0.93^{ABa}	-17.77±0.45^{Bcd}	-18.43±0.49^{ABab}
3	-16.00±0.37^{ABc}	-16.96±0.79^{Ab}	-15.94±1.59^{ABb}	-14.85±0.77^{Bb}	-15.96±0.64^{ABd}	-16.57±1.40^{ABb}
4	-17.52±0.40^{Abc}	-18.30±0.20^{Aab}	-18.91±1.18^{Aa}	-18.64±1.37^{Aa}	-18.62±0.16^{Abc}	-18.65±0.97^{Aa}
5	-19.89±0.53^{Aab}	-20.95±0.45^{Aa}	-20.02±0.31^{Aa}	-19.92±1.79^{Aa}	-20.80±0.71^{Aa}	-19.97±1.11^{Aa}
6	-19.76±0.95^{Aab}	-18.93±1.70^{Aab}	-20.45±0.90^{Aa}	-19.38±0.16^{Aa}	-19.09±0.13^{Aabc}	-19.35±0.47^{Aa}

Note: Data was expressed as means ± sd, n=3, mV
abc means on the same row without a common subscript are significantly different (*P*<0.05).
ABC means on the same column without a common subscript are significantly different (*P*<0.05)

1.4.9 Free fatty acid

There's no pronounced change of the FFA content was found during storage period for 6 month. Besides, no pronounced rule was found with the raw milk SCC and the storage temperature.

Table 1-9 The content of free fatty acids of UHT milk during storage

Storage month	LSCC temperature(/°C)			HSCC temperature(/°C)		
	20	30	40	20	30	40
1	$0.02±0.00^{Aa}$	$0.02±0.01^{Aa}$	$0.09±0.04^{Bb}$	$0.02±0.01^{Aa}$	$0.05±0.02^{ABa}$	$0.04±0.01^{Aa}$
2	$0.02±0.02^{ABa}$	$0.01±0.00^{Aa}$	$0.03±0.01^{ABa}$	$0.02±0.01^{Aa}$	$0.03±0.01^{ABa}$	$0.04±0.02^{Ba}$
3	$0.03±0.01^{Aa}$	$0.04±0.01^{Aa}$	$0.05±0.01^{Aab}$	$0.04±0.00^{Aab}$	$0.04±0.01^{Aa}$	$0.05±0.02^{Aab}$
4	$0.02±0.01^{Aa}$	$0.05±0.05^{ABa}$	$0.05±0.03^{ABab}$	$0.05±0.03^{Aab}$	$0.17±0.12^{Bb}$	$0.07±0.04^{ABab}$
5	$0.10±0.06^{ABb}$	$0.06±0.06^{Aa}$	$0.18±0.01^{Bc}$	$0.07±0.04^{Ab}$	$0.09±0.07^{ABab}$	$0.14±0.05^{ABc}$
6	$0.03±0.01^{Aa}$	$0.04±0.01^{ABa}$	$0.06±0.02^{Bab}$	$0.03±0.01^{Aab}$	$0.05±0.01^{ABa}$	$0.11±0.01^{Cbc}$

Note: Data was expressed as means ± sd, Free fatty acid unit is expressed as absorbance OD value
abc means on the same row without a common subscript are significantly different (P<0.05).
ABC means on the same column without a common subscript are significantly different (P<0.05)

1.4.10 Conclusion

Under different storage temperature, 20,30,40°C, samples were stored for 180 days and tested every 30 days for proteolysis and fat hydrolysis indexes. Our results show that milk plasmin and plasminogen activity of both SCC level milk has basically complete deactivation. All samples underwent a slight decrease in viscosity, both temperature and body cells caused no significant difference in the change. Lipase activity trend similar to this, no significant changes was found during the entire storage. From proteolytic conditions and casein RP-HPLC results, we found that during storage, protein and casein hydrolysis are serious, predominate the hydrolysis of casein areβ- casein, κ- casein, indicate that involved in protein hydrolysis enzymes include plasmin and enzymes produced by psychrophile. In addition, each group UHT milk have been increased acidity, increased fat globule diameter, darken color and fat floating phenomenon, these problems may be in close relationship with proteolysis and Maillard reaction. On the contrary, the impact of SCC of raw milk on the indicators are not significant, no pronounced change of lipase and plasmin activity and free fatty acid (FFA) was found. Overall, the low storage temperature for maintaining the quality of UHT milk is more beneficial, whereas raw milk SCC had relatively less influence. This conclusion may be a reference from aspects of raw milk SCC and storage condition to UHT milk quality control.

Chapter 2 2014-R2 Corn/hay - feeding efficiency

Questionnaire of production and management of dairy farms in china in 2014

2.1 About Principle Investigator

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Short Curriculum Vitae

She works in China Agricultural University since 1998, and her major research area is in ruminant nutrition. She studied ruminant physiological nutrition during her PhD period in the University of Guelph in Canada. Before that, she finished her Master's and Bachelor's degrees on animal nutrition in China Agricultural University.

2.2 Introduction

In recent years, The ministry of agriculture of the People's Republic of China (MOA), Dairy Association of China (DAC) and Dairy industry and Technology system (CDITS) had collected large amount of data about dairy industries and followed up the development trends of China's dairy sectors, but these data were mainly focused on economical and trading condition about dairy industries instead of basic information from dairy farms. After China dairy scandal in 2008, government set severe regulatory policies for Chinese dairy production sectors to guarantee the safety of dairy products (Mo and Huang et al., 2012). In a recent survey, feed conversion and nitrogen utilization efficiency, and the quantity of human-edible grains fed in different dairy farming systems were calculated using data collected from 24 dairy farms in China (Wang and Liu et al., 2014). Wang J. in 2008 carried out a study about China Dairy United dairy farming and compared it with other dairy farming systems in China (Wang and Chen et al., 2015). Although both of previously mentioned researches revealed some details on China's dairy farming, neither of them gave a comprehensive perspective on the real production situation of dairy farms.

The current survey carried out to 1) reveal details on dairy farms in China 2) reveal the most influential on-farm parameters which affected MP and productivity of dairy cows in China 3) make a comparison between China's dairy farm situations with that of United States of America.

2.3 Materials and methods

2.3.1 Data collection

The whole survey was executed in 2014, and 205 dairy farms from 13 provinces and/or cities in China were involved. All farms were enrolled in Dairy Industry and Technology System (CDITS) in China. A questionnaire was designed to acquire the information on farm management and production situation during 2014.

The questionnaire was designed by researchers of CDITS. Dairy farms were selected in different provinces with different properties and scales to cover the main dairy farming regions in China. The questionnaire contained a total of 50 questions including multiple choices and closed questions.

Questionnaires were sent to farm's managers via e-mail by scientists from CDITS in different provinces, and questionnaires were checked by CDITS after being filled. In case of any problem regarding to questionnaires, the farmers or farm managers were contacted once again to verify the given information.

Information obtained from questionnaires were used to calculate fat corrected 4% FCM and feed efficiency: 4% FCM = (0.4 × test-day milk yield) + (15.0 × fat yield) (Keller Mayer and Dowd et al., 2011), Feed efficiency=4% FCM/dry matter intake.

2.3.2 Statistical analysis

Questionnaires less than %5 of questions were answered were excluded from statistical analyses. The normality of continuous variables were tested using UNIVERIATE procedure of SAS (SAS Institute, 2009). Data variance analysis on milk production, SCC, bacteria count, milk fat, milk protein, milk price among different province using the ANOVA procedure of SAS. Regression analysis was conducted to model the relationship between farms characteristics and milk production using the GLM procedure of SAS 9.2 (2003). Reliability test was conducted to test the quality of the questionnaires using SPSS software (Zhe, 2009).

2.4 Result

2.4.1 Survey response

Quality analysis of questionnaires revealed that in total 205 questionnaires including 10,250 questions were filled of which 872 questions were not answered accounting for 8.5% of total questions in questionnaires. Reliability test showed that the Cronbach's α index was larger than 0.8.

Farm demographics

A total of 205 dairy farms were enrolled in this study from 13 provinces and/or large cities in China. These provinces and/or cities were the main dairy farming were as in China. The dairy farms covered in this study were 14 in Beijing city, 19 in Tianjin city, 20 in Hebei province, 10 in Henan province, 4 in Ningxia province, 26 in Inner Mongolia province, 30 in Heilongjiang province, 10 in Gansu province, 20 in Xinjiang province, 19 in Liaoning province, 10 in Shanxi province, 12 in Shaanxi province and 10 in Shanghai city. The questionnaires covered the information of 243,920 milking cows, 140,220 heifers, 29,888 calves and 88,984 new born calves.

The average herd size in surveyed farms was 1202. Average herd sizes in a descending order were Heilongjiang 2457, Beijing 1659, Shaanxi 1269, Liaoning 1237, Xinjiang 1161, Shanxi 1026, Ningxia 969, Tianjin 915, Henan 914, Hebei 866, Gansu 653, Shanghai 653, and Inner Mongolia 648 heads.

The survey covered 120 corporate dairy farms, 34 private farms, 31 cooperate farms, 15 commune farms, 4 milking stations and 1 household dairy farm. Corporate dairy farms comprised 58.8% of enrolled farms with a total number of 188,963 cows. It was found that farm type had significant influence on MP (P<0.0001). Milking station had the highest average MP 30.33±4.06 kg and highest FE among the different types of surveyed farms.

2.4.2 Milk parameter

Average milk production in 205 selected dairy farms were 25.4±4.14 kg, with the maximum and minimum of 37.56 kg and 15.00 kg, respectively. MP differed significantly among the provinces/cities studied in this survey (P<0.0001). Average MP of provinces in descending order was: Ningxia 33.33±0.58 kg, Beijing 30.96±1.84 kg, Tianjin 28.13.50 kg, Henan 27±2.43 kg, Xinjiang 26.18±5.76 kg, Shanghai 25.60±2.99 kg, Hebei 25.49±3.69 kg, Heilongjiang 25.43±4.19 kg, Liaoning 25.06±4.48 kg, Shanxi 24.12±3.39 kg, Shaanxi 23.73±2.85 kg, Gansu 23.70±1.89 kg, Inner Mongolia 22.17±3.04 kg. In China, it is a common practice to divide lactating dairy cows into high production (HPG), medium production (MPG) and low production groups (LPG). The results of present survey showed that average milk production in HPG was 33.54±4.59kg with a maximum and minimum of 60 and 16 kg, respectively. There were significant differences between farms with regard to MP of HPG (P<0.0001). Average MP of HPG cows in the provinces/cities studied in a descending order was: Ningxia 44.8±0.29 kg, Shanghai 40.0±6.68 kg, Beijing 36.0±4.16 kg, Hebei 34.2±4.06 kg, Xinjiang 34.2±8.93 kg, Henan 34.0±4.84 kg, Liaoning 34.0±3.98 kg, Heilongjiang 33.3±4.73 kg, Tianjin 33.2±5.10 kg, Gansu 32.6±2.66 kg, Shaanxi 31.4±3.46 kg, Shanxi 31.6±2.92 kg, Inner Mongolia 30.3±2.98 kg. Significant differences were observed in MP of MPG lactating dairy cows among provinces/cities studied in the present survey. Average MP of MPG was the highest in Shanghai (31.57±7.63 kg) and the lowest in Inner Mongolia (22.76±3.01 kg). The results of present survey showed that LPG lactating dairy cows in Shanghai, Beijing and Ningxia had a higher MP compared with the LPG cows of other provinces/cities level.

Milk fat, milk protein, milk price, SCC, bacteria count were difference in different provinces/cities. Average milk fat content in 205 farm were 3.88±0.8% with the maximum and minimum of 4.1% and 3.1%, respectively. Farms in Hebei, Ningxia and Inner Mongolia produced milk with the highest fat content (more than 4.0%), while milk produced in Shanghai farms had the lowest fat content (3.6±0.14%). All farms in the present study produced milk with fat content higher than 3.6%. Average milk protein content in the farms was 3.19±0.20%. Dairy farms in Henan, Ningxia, Heilongjiang, Xinjiang, Liaoning and Shanxi provinces produced milk with average milk protein content higher than 3.2%.

Average milk protein content of farms in Beijing, Tianjin, Hebei, Inner Mongolia, Gansu, Shaanxi and Shanghai was lower than 3.2%, with Shaanxi's farm had the lowest milk protein content (3.07±0.05%). Average bacteria count in 205 dairy farms was 14 × 1000 cells/mL. Average milk bacteria count in Shanxi's dairy farms was the highest (41.67±15.86 × 1000 cells/mL). Also, average milk bacteria count in Henan dairy farms was higher than 20 × 1000 cells/ml), while milk bacteria counts in Beijing, Ningxia, Shaanxi and Shanghai dairy farms were lower than 10 × 1000 cells/ml. Milk bacteria counts in Hebei, Xinjiang, Liaoning dairy farms were in the range of 10 to 20 × 1000 cells/mL. SCC also differed among dairy farms of surveyed provinces/cities. Overall, average SCC was 31.48 × 1000 cells/mL. Average SCC in Ningxia dairy farms was lower than 19 × 1000 cells/ml. Milk produced in Xinjiang, Inner Mongolia, Beijing, Gansu, and Henan were with SCC higher than 30 × 1000 cells/ml, while milk produced by Tianjin, Hebei, Liaoning, Heilongjiang, Shaanxi and Shanghai dairy farms were with SCC lower than 30 × 1000 cells/mL. Milk price also was different in provinces/cities covered by this survey with an average 4.12 RMB/kg in 2014. Average milk price in 13 provinces/cities of China was highest in Liaoning (4.62 RMB/kg) and lowest in Xinjiang province (3.48 RMB/kg). Average milking day in 205 dairy farms assessed in the present survey was 222.9±49.67 days, with average milking days of 149.26±67.48, 217.13±53.45, and 276.34±65.83 days for HPG, MPG and LPG, respectively.

2.4.3 Ration and dry matter intake

Analysis of questionnaires showed that dairy cows had an average DMI of 20.1±2.89 kg. Average DMI in HPG, MPG and LPG were 22.6±2.80 kg, MPG 19.76±2.86 kg and 16.95±2.86 kg, respectively. Dairy cows in in Xinjiang dairy farms had the highest average DMI. Average DMI in cows of Hebei, Inner Mongolia, Heilongjiang, Gansu and Shaanxi dairy farms was lower than 20 kg/day. In other provinces/cities, average DMI was higher than 20 kg/day. Average concentrate fed were 12.17±2.31 kg, 9.77±2.38 kg and 7.29±2.34 kg/day in HPG, MPG and LPG, respectively. Average ords rate in HPG, MPG and LPG was 4.29, 4.21 and 3.54 %, respectively.

Average dietary cost for different production groups and different provinces/cities were calculated. In 205 dairy farms, average dietary cost was 55.35 RMB/cow /day in November of 2014, with average of 66.83 RMB/cow, 53.7 RMB, and 41.34 RMB/cow for HPG, MPG and LPG, respectively. Analysis of dietary cost by different province showed that dietary cost was the highest in Shanghai dairy farms (70.0±8.83 RMB/cow) and the lowest for dairy farms of Liaoning province (43.4±6.33 RMB/cow).

The main forages with their respective dry matter content included in the rations of dairy cows in farms were studied in the current survey. Overall, mean forage utilization rate in dairy farms of 13 provinces/cities for corn silage, sheep hay, domestic alfalfa, imported alfalfa and oat hay, corn stalk silage, wheat straw, and peanut vain, were 94.82%, 76.17%, 65.95%，56.48%，37.82%，24.87%，30.31% and 8.29%, respectively. Average moisture content of corn silage and corn stalk silage was 75.57±3.48% and 71.00±4.91%, respectively.

2.4.5 Feed efficiency

Overall average FE of all farms studied were 1.27±0.18, and 1.48±0.19, 1.24±0.19, 0.98±0.25 for HPG, MPG and LPG lactating dairy cows. With respect to FE dairy farms of Ningxia and Tianjin were the best (1.48±0.06 and 1.41±0.23, respectively) and Xinjiang, Liaoning, Shanxi, Inner Mongolia dairy farms were the worst with a mean FE of lower than 1.2. High producing dairy cows in dairy farms of Ningxia province had the highest FE (1.78±0.01), the second was Shanghai province (1.74±0.27), and the lowest was in Xingjian dairy farms (1.29±0.25). Feed efficiency of MPG cows could roughly reflect the real feed efficiency of lactating dairy cows in China's dairy farms. Feed efficiency of MPG lactating cows in provinces/cities surveyed was studied, and it was highest in dairy farms of Shanghai (1.5±0.26) and lowest in Liaoning's dairy farms (1.1±0.14). In the LPG, Ningxia's dairy farms also had the highest FE (1.19±0.07), LPG in dairy farms of Beijing, Tianjin, Hebei, Gansu, Shaanxi, Shanghai had FE higher than 1.0 and those of in Henan, Inner Mongolia, Xinjiang, Liaoning, Shanxi's dairy farms had FE lower than 1.0.

2.4.5.1 Reproduction situation and major disease

Present survey showed that the most prevalent diseases in Chinese dairy farms were mastitis, foot disease, reproductive diseases and metabolic diseases. From 205 dairy farms enrolled in present study, 106 dairy farm managers selected mastitis as the most important disease in 2014 (with a 59.89% of total farms); 54 managers selected foot disease as the major disease in their farms (30.51% of total farms); 50 farm managers selected reproduction diseases including metritis, infertility, placenta retention as the most prevalent disease in their farms (in total with a 28.25% of total farms); 32 farmers thought that metabolic diseases mainly including diarrhea were most abundant in their herds (18.08% of total farms); and 25 farms selected postpartum diseases as the main diseases of their herds (14.12% of total farms).

Results of current survey showed that average reproduction rate, was 80.13±8.6%. Accordingly, conception rate was 47.24±10 %, average age at first calving was 24.97±1.7 months and average calving interval was 15.27±5.7 months.

2.4.5.2 Feeding

From 205 dairy farms, 140 farms fed their cows three times a day, 53 farms fed twice daily and six fed their cows once a day. Average frequency of ration pushing was 6.03±3.2 times a day. Feeding methods were divide into total mixed ration (TMR) and others. Results of present survey showed that 92.6% of dairy farms were using TMR for feeding their animals.

2.4.5.3 Housing systems

Our survey showed free stalls were accounting for 89.16% of dairy farms, and the rest 10.84% of farms were using tie stalls.

2.4.5.4 Manure processing

Dairy farms of China either process manure manually or automatically. Hundred and thirty four dairy farms accounting for 68.7% were using automatic manure cleaning systems and the rest 31.3% were removing manure from their barns manually. Regarding to manure utilization, 144 dairy farms had stacking fermentation (76.19% of farms), 36 farms processed manure by solid-liquid separation (19.05%), and 9 farms had both manure processing accounting for 4.76% of farms.

2.4.5.5 Barn condition

Questionnaires also had four questions about barn conditions. According to current survey, in most farms (58.56 %) the preferred bedding material was sand, followed by dry feces (17.13 % of farms), rubber (16.53 % of farms), and saw dust (1.66% of farms). The rest (6.08% of farms) used other types of bedding materials in their barns.

Yard surface of the dairy farms was consisted of ground (55.41% of farms), bricks (17.20% of farms), mixed concrete (21.66% of farms), and the rest of farms had other types of construction materials (19.6% of farms).

Selected farms used different types of materials for yard padding including sand (64.88% of farms), sawdust (1.79% of farms), dry feces (30.36% of farms), rubber (1.19% of farms) and other types of material (1.79% of farms).

Barn floors in farms mostly covered by concrete (91.36 % of farms) followed by brick (3.70% of farms). Farms in which their barn floors were covered with no construction materials (ground) were accounting for 1.23% of surveyed farms, and the rest used other types of construction materials on their barn floors.

2.4.5.6 Milking information

Most farms milked their lactating cows three times daily (73.63% of farms), followed by twice daily (24.38%) and once a day (1.99%).

Questionnaire had one question about milking equipment suppliers. Our survey revealed that 46.34 % of farms were equipped with milking machines from Delaval company, 27 farms were using milking equipment of WestfiaSurge company (13.17% of farms), 11 farms used Afimilk's equipment (5.37% of farms), 10 farms were using Dadulin milking equipment (4.88% of farms) and 30.24% of farms were using milking equipment from other companies.

From farms studied in this survey, only 10 farms (4.88% of farms) were not selling their produced milk to the factory. Our survey revealed that 55 farms supplied milk to Inner Mongolia Yili Industrial Group Limited by Share Ltd (20.74% of farms), 39 dairy farms supplied milk to Mengniu (29.26% of farms), 21 farms supplied milk to Bright Milk (11.17% of farms), 12 farms were selling their milk to Sanyuan (6.34% of farms), 10 farms were providing milk to Yinqiao (10 5.32% of farms), 10 farms were suppliers of American Dairy (5.32% of farms) and 41 farms supplied milk to other factories (21.81% of farms).

2.4.5.7 Sperm providers

The top six frozen sperm providers to dairy farms of current survey were Beijing dairy breeding center (BDCC) (19.38% of farms) Alta-Agricorp (13.95% of farms), Semex (11.63% of farms) Sk-xing (10.47% of farms), Improved Varieties Subsidy (10.08% of farms) and ABS (9.69% of farms).

The objective of this study was to provide a comprehensive overview about current situation of China dairy farms with regard to managerial and production parameters. MP, DMI, FE, management parameters, herd demographics, ration characteristics, housing condition and information on prevalent diseases were included in the present survey. The present survey showed that production performance differed among dairy farms of provinces/cities studied. According to our survey, there was a gap between Chinese and high level dairy farms among the world on production performance and managerial parameters. This study offers a comprehensive understanding about production and management situation in China's dairy farms in comparison with those of American dairy farms, which will help decision makers of China's dairy sectors to fill the gap between Chinese and high level dairy industry among the world.

Chapter 3 2014-R3 Farm Development

Cow Farm Size Development in North China

3.1 About Principle Investigator

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Short Curriculum Vitae

Education

2006.12	Ph.D, Economics, Washington State University
2003.6	M.S., Agricultural Economics, Chinese Academy of Agricultural Sciences
1998.6	B.S., Economics, China Agricultural University

Fields of Specification

Consumer and health economics

Food safety and policy

Environmental economics and sustainable development

Professional Experience

2014-present	Professor, College of Economics & Management, China Agricultural University.
2016.1-present	Director, Center for Food and Health Economic Research (C'FHER), CAU.
2015.7-present	Visiting professor, Department of Agricultural and Resource Economics, UC Davis.
2013-2014	Associate professor, College of Economics & Management, China Agricultural University.
2009- 2013	Assistant and Associate professor, Center for Chinese Agricultural Policy, Chinese Academy of Sciences.
2007-2008	Research associate, International Marketing Program for Agricultural Commodities and Trade (IMPACT) Center, WSU.

Personal Web

http://cem.cau.edu.cn/art/2015/3/23/art_3670_121.html

3.2 Objectives of the study

(1) To understand the status quo of cow farming and the distribution of cow farming in terms of herd size in the Great Beijing area.

(2) To study the impacts of growing scale on cow farming practices and production efficiency.

3.3 Main report of the research:

3.3.1 Background

Dairy farming in many countries has experienced a small to large scale expansion. MacDonald, et al. (2007) found that from 1970 to 2006, the number of dairy farms in the United States reduced from 648,000 to 7,500, reduced by about 88%. During the same period, the average herd size increased from 19 to 120; Zimmermann and Heckelei (2012) indicated that in the EU 15 countries the number of dairy farms declined at an annual rate of 3.5% from 1995 to 2005. Similar pattern can also be found in Japan (Schluep Campo and Beghin, 2006), South Korea (Song and Sumner, 1999; Lee, et al., 2006).

Dairy farming scale in China is experiencing the similar evolution as in above developed countries. Lu, et al. (2009) study shows that in the early 21st century, China's dairy farming was dominated by small-scale farm. On average, 80% of total milk production was from small-scale cow farming. At the same time, the number of dairy farmers was rapidly reducing. This is also true in traditional dairy production provinces (Jia, et al., 2012). According to Dairy Industry Development Report, there were 344 cow farms in China with herd size over 500 heads in 2002, with average 1,451 milking cows in each farm. The well-documented food safety issues partially contributed to the rapid development of cow farm scale (Xiu et al., 2010).

The growing herd size is the result of changes in production mode, but it will in turn bring new impacts on dairy production, such as technology adoption, negotiating power in market, environmental pressure, new practices and standards for milk safety control, commercial feeds utilization, and so on. However, empirical analyses on the economic impacts of the increasing herd size on these aspects are insufficient in China. Several questions in particular include: (1) How will the growing herd size affect cow farmers' new technology adoption, practices in managing inputs, food safety, manure treatment, and so on? (2) Given various constraints, what would be future trend of cow farm development? And (3) What are impacts of cow farming scale development on milk quality and market development? Answering these questions are undoubtedly able to draw some implications for policy making and the sustainable dairy industry development in the study area and beyond.

3.3.2 Data

The data used in this study are from a field survey conducted in Beijing, Tianjin and Hebei in the summer of 2015. Through local dairy associations and related government sector, we selected 126 cow farming units by herd scale measured in cow inventory size in 2014 (including farm scaled less than 100 heads, 100-299, 300-499, 500-999, 1000-1999, and 2000 or above) for the survey. The survey was done by interviewing the representative from each selected unit in paper and face-to-face. The total sample includes 67 cow farming units from Hebei, 21 units from Tianjin, and 38 units from Beijing.

3.3.3 Main results from the survey

Small-scale cow farms are in a fast track to disappear. As shown in Figure 3-1, farms with less than 100 head of cows in inventory in the sample only accounts for about 20 percent. In contrast, farms with 500 head of cows or more accounts for about half in our sample. In Beijing and Hebei, cow farming is almost dominated by large-scale farm units who have cows over 300 heads in 2014. It must be noted that this result might heavily related to our sampling method. To what degree this result can reflect the population in this area is a question we cannot answer due to information limitation. Even so, this result, along with our field observations, strongly suggest that the space for small-scale farms has been shrinking rapidly in recent years in the study provinces.

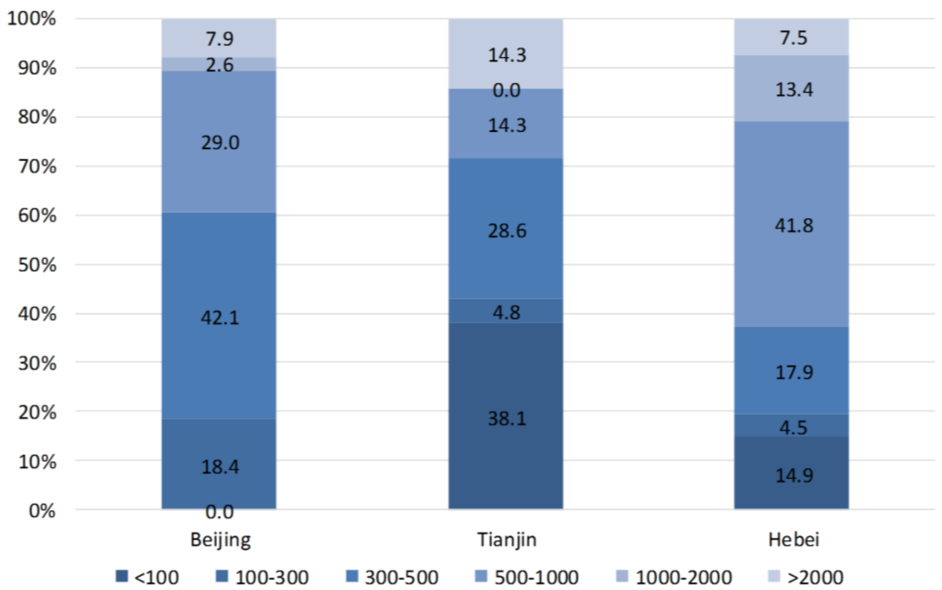

Figure 3-1 Sample distribution by province and farm scale

1. Cow farm scale has been moving up fast in the area. The survey results show that there were about 3.3 percent of cow farms operating in in small-scale, having less than 100 heads in inventory, in the area in 2010, but this size of farms has completely moved up to larger scale in 2013 and 2015. Noted that the small-scale farms that have run out of business since 2010 cannot be captured in our survey. During the same period, even the proportion of medium-scale farms (100-300 heads) in total number of operating farms has declined. In contrast, large-scale farms (500+) or even super large-scale farms (1000+) have sustainably expanded. From the point view of farm operational model, enterprise running farms (refer to as "enterprised farm") dominates in our sample, accounting for 73.1 percent in unit

number in our sample (Figure 3-3). Following it is family-based farms (12.5 percent) and farm base (*yang zhi xiao qu*) (9.6 percent). Farms operated by integrated enterprises in dairy industry (*yi tiao long qi ye*) (refer to as "integrated farm") and farmer corporative (refer to as "Coop-operated farm") together contribute to 5 percent in the sample in terms of sample unit. Farm scale varies by farm operational model. For farm base, medium-size (300-500 heads) and large size (500 heads or above) dominates, together accounting for near 80 percent. For family-based farms, the most common size is less than 300 heads.

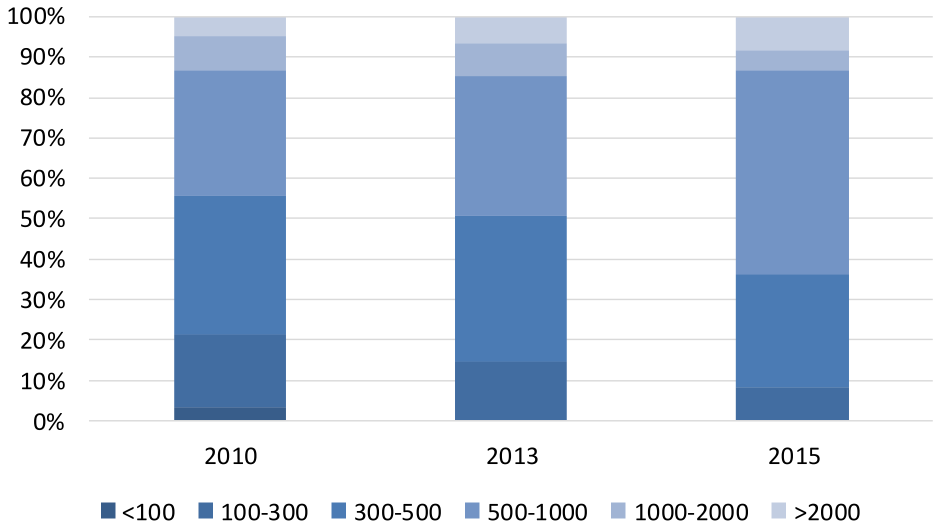

Figure 3-2 Farm scale distribution by year

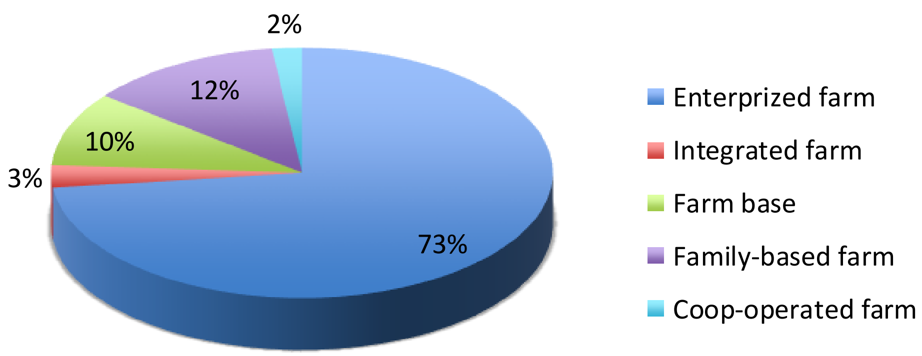

Figure 3-3 Farm distribution by operational model

2. The expansion of cow farm positively contributed labor input efficiency and labor quality. As we can see in Figure 3-4, employee number declines sustainably with farm size expansion. For farms scaled

between 100 and 300 heads of cow, roughly 4.6 employees are needed for per hundred cow, while the number sharply declines to 2.5 persons for farms scaled 2000 head of cow or above. Moreover, as farm size goes up, the proportion of full-time employees in total labor forces hired increases. For farms with 500 heads of cow, over 90 percent of employees are full-time labors. The proportions of skilled employees and highly educated employees in line also increase with farm scale growth (Figures 3-4 & 3-5).

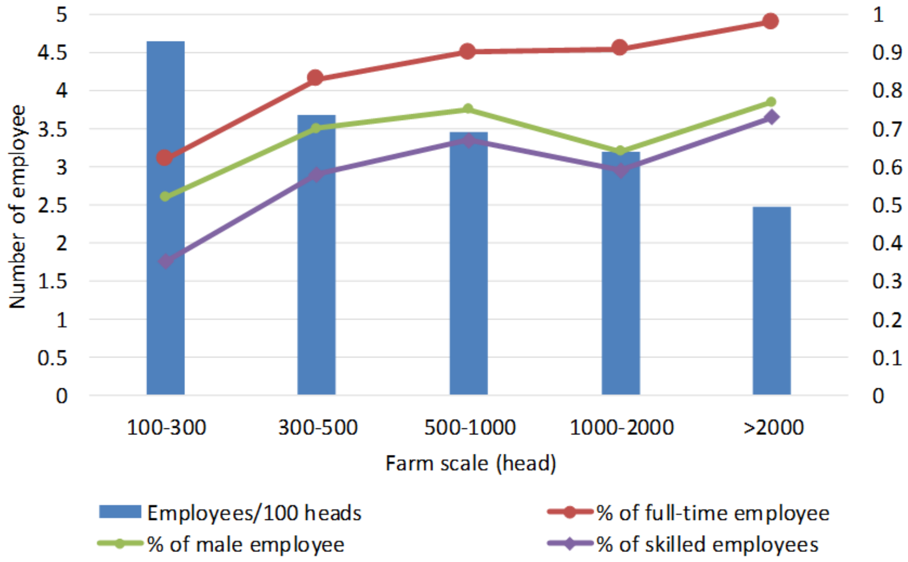

Figure 3-4 Employees per 100 cow and structure

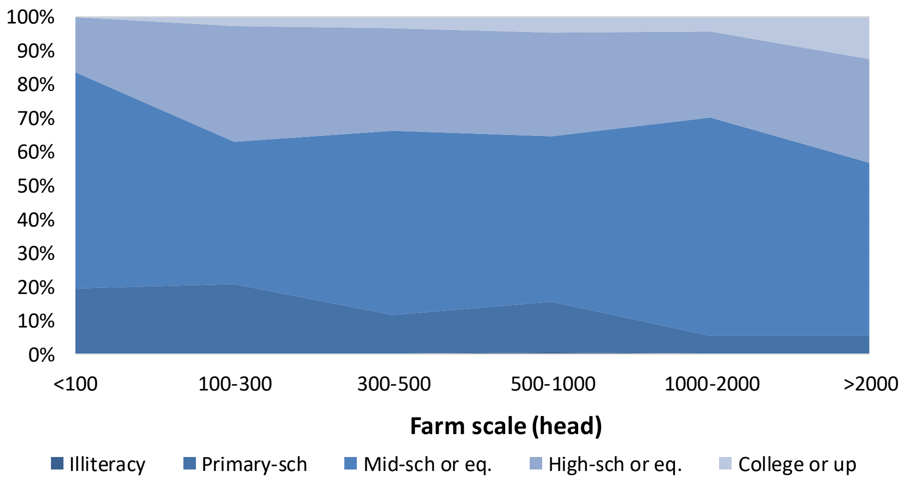

Figure 3-5 Employees' education by farm scale

3. A majority of farms in our sample are well equipped with infrastructure and modern facilities. As shown in Table 3-1, modern facilities such as ventilation and cooling system, manure collection and treatment system, batching house, milk cooling tanks, and milking house have been fully equipped in

various scale of farms. The adoption rate of soft bed, software for farm base management, and DHI are also linearly growing farm scale and to rise to over 80 percent for farms scaled 500 or above.

Table 3- Farm infrastructure and facilities equipped

	100-300	300-500	500-1000	1000-2000	>2000
Ventilation & cooling system	100	100	94.7	100	100
Manure collection	100	100	94.7	100	100
Milking house	100	100	100	100	100
Cooling milk tanks	85.7	100	100	100	100
Batching house	100	88	97.2	100	100
TMR	83.3	100	100	100	100
Soft bed	50	96.3	81.8	100	100
Farm base management software	33.3	70.0	81.6	88.9	100
DHI participation	83.3	50.0	75.0	62.5	80.0

4. Yield rises with herd size expansion, but is quite varied by operational model. In 2015, a milking cow averagely produce 24.1kg of milk per day in small scale farms with less than 300 heads of cow, and near 30kg in large scale farms with more than 1000 heads of cow in line (Figure 3-6). The maximum and minimum yields are also increasing with farm scale with slight difference in variation. By operational model, integrated farms have the highest yield, producing 32kg per milking cow per day, which is about 5 kg higher than that of enterprised farms (27.6kg), family-based farms (27.4kg), and coop-operated farms (26.5kg). Farm bases, on another side, produce the lowest yield, being just 23kg per milking cow per day.

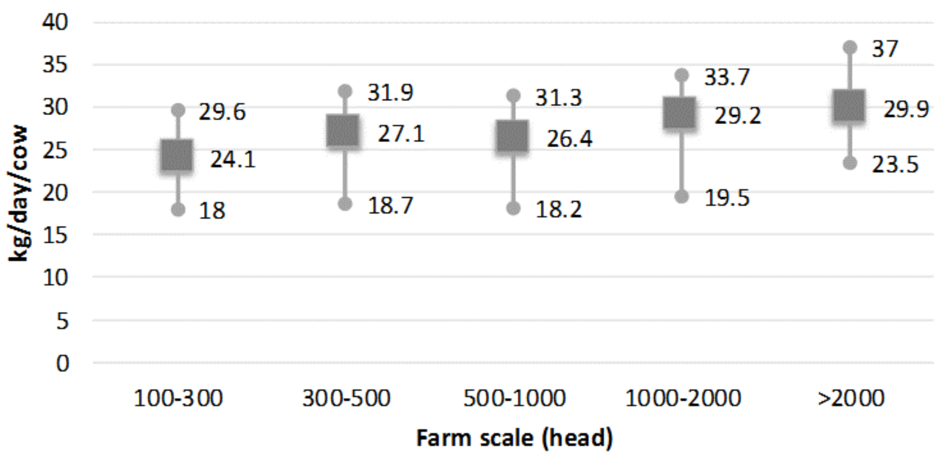

Figure 3-6 Mean yield and variations by farm scale

5. Larger farms averagely perform better in milk safety than small-scale farms, but farm size does not affect nutrient content significantly. The results presented in Table 3-2 indicate that the number of

cell and bacteria per ml of fresh milk is about 403,000 and 193,000 units, respectively, in farms scaled less than 300 heads of cow. Both numbers go down sharply for farms with scale greater than 300 heads and become stagnated. The stagnation suggests that once farm scale reaches 300 heads high, further size expansion will not be that beneficiary in milk safety improvement. The improved performance in cell and bacteria numbers ensure that the large-scale farms with higher sale price in market and lower sale rejection rate in comparison with their small-scale counterparts. Table 3-2 also shows that integrated farms perform the best in all safety and nutrition indicators listed, while farms at farm base are on another side in overall, suggesting that the farm base model which once was highly expected in solving milk safety problems since the disclosure of melamine-contaminated baby formula indeed lack ability for sustainable development.

Table 3-2 Milk safety indicators, nutrient content, and price

	100-300	300-500	500-1000	1000-2000	>2000
Cell (10,000 unit/ml)	40.3	29	31.3	23.6	24.9
Bacteria (10,000 unit/ml)	19.3	8.3	12.2	7.7	11.1
Fat(%)	3.9	3.68	3.74	3.8	3.8
Protein(%)	3.31	3.02	3.1	3.14	3.18
Average sale price (yuan/kg)	3.37	3.94	3.95	3.98	4.06
Sale rejection rate (%)	0.75	0.73	0.66	0.69	0.5

Table 3-3 Milk safety indicators, nutrient content, and price by operational model

	Enterprisied farm	Integrated farm	Farm base	Family Based farm	Cooperated farm
Cell (10,000 unit/ml)	29.2	18.2	42.5	28.5	30
Bacteria (10,000 unit/ml)	10.1	2.5	21.3	7.9	28
Fat(%)	3.73	4.02	3.67	3.82	3.8
Protein(%)	3.09	3.3	3.11	3.15	3.25
Average sale price (yuan/kg)	3.97	4.4	3.53	3.99	3.95

6. Feed cost per cow is significantly lower for large-scale farms than medium- and small-scale farms. Ration per cow is 158 yuan for farms scaled less than 300 cows, which is about 50 yuan higher than medium- and medium-large-scale farms (300-1000 cows), and nearly twice high as that for large- (1000-2000 cows) and super large-scale farms (Table 3-4). Roughage and concentrate evenly contribute to ration cost at all farm scale levels. By farm operational model, farms in farm base have the highest ration cost, largely due to the highest concentrate uses, and integrated farms have the lowest ration cost (Table 3-5).

Table 3-4 Feed cost per cow by farm scale

	100-300	300-500	500-1000	1000-2000	>2000
Ration (yuan/cow)	158	107	123	85	69
Roughage (yuan/cow)	78	35	47	34	38
Concentrate (yuan/cow)	80	72	76	51	31

Table 3-5 Feed cost per cow by farm operational model

	Enterprised farm	Integrated farm	Farm base	Family-based farm	Coop farm
Ration (yuan/cow)	112	62	166	80	81
Roughage (yuan/cow)	47	29	32	36	43
Concentrate (yuan/cow)	65	33	135	45	38

7. Farm size may further expand in the area in the future. During the survey, we asked the owners of selected farms about their future plan for farm size development. The results show that on average about half of farms planning further expansion while about one the third said they would not change and only small proportion of farms planning to reduce farm size. Also, as one can clearly see that, the larger farms the more aggressive in the future size development.

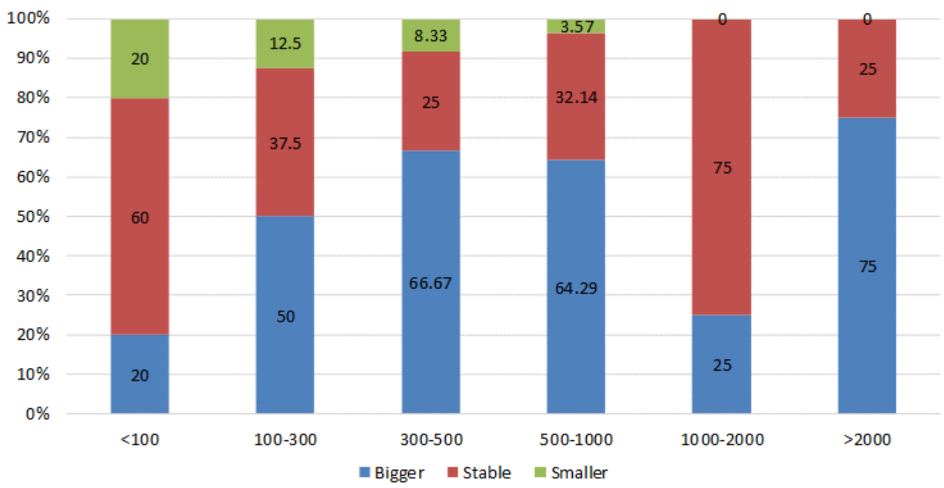

Figure 3-7 Prospective plan for future development of farm size

3.4 Conclusion

Our findings in this study consists of one concluded part and one likely but unconcluded part. The concluded part is, feeding cost, production efficiency, milk safety, farm management, and so on so forth, are all benefited from cow farm size growth in the study area.

The likely but unconcluded part is about the farm size itself. The observed farm size from our survey is way beyond (above) our anticipation. If one calls the representative family based cow farming model in EU countries and the representative commercial cow farming model in Japan and Korea as modern cow milk production model, we would say that cow farming in the Great Beijing area has turned into a post-modern era. This is not only talking about the way larger farm scale compared to China's industrialized counterparts, but also about the definitely comparable farm infrastructure and modern facility equipment, and the yield as high as in Japan, Korea, and the United States. And, the farm size in the study area is still growing, and potentially not stop in a near future. The reliability of this finding depends on to what extent our sample can represent the population in these three provinces, which unfortunately goes beyond our capacity to test at this moment. But, our field observations, along with the encountered extreme difficulties in finding the "anticipated" small-scale farms during the survey, tell us, the found farm size, even if unconcluded, could be very likely true.

At the end, we would like to share our mixed feeling by looking at this likely true result. On one hand, it is no doubt that the growing farm size has positively contributed to cow milk production in multiple dimensions as we have realized. This is good. On the other hand, we cannot help asking ourselves, have we gone too far away from we should? In 2008, the globally well-known melamine-contaminated baby formula scandal and a number of following scandals disclosed have boosted a series top-down policy interventions and massive social and industrial responses. As a result, China's cow farming industry has headed to a fast- or faster track toward a happy world full of large-scale commercial cow farms. But there are at least three big concerns in our mind:

First, why we have not seen a significant drop of milk price in store? I have to check around very careful in front of store shelves full of small but extremely expenditure milk boxes when I am in China, but I don't even look at the price label when I am shopping in stores in the US and many countries in Europe. Why? Has China's dairy become a capital game? If the significantly improved production efficiency due to scale development could not eventually benefit consumers, why do we need them to be large?

Second, with the rapid expansion of farm size, the competition between farm and local residents for natural resources such as arable land, surface and ground water, the negative impacts on local ecosystem due to manure disposal, and potential anthropozoonosis, etc. will certainly become severe and severer. And, it is not completely impossible for some cases to develop into badly social events. There are a lot of lessons we can learn from the world. So, why do we need these cow farms to be so huge? For conventional dairy countries, average farm size never become this huge as we saw in the study area. Netherlands, a traditional dairy producer and exporter in the world, average farm size is less than 55 cows. Ireland, another long-history dairy exporter in the world, average cow farm size is about 60 cows. New Zealand, grassland farming and the largest dairy exporter to China's market, average farm size is less than 400 cows. Australia, another significant player in milk exports to China, average farm size is about 280 cows. Japan, following its near fifty-year farm size growth since the 1960s, average farm size in commercial cow farming today is slightly above 70 cows. Korea, another commercial cow farming Asian country, average farm size is about 70 cows. The United States, the largest milk producer in the world, average cow farm size in commercial farming is below 200 cows. India, this second largest milk producer in the world, average farm size is between 1 and 3 cows.

Last, but the most important, is it surely right to force real small-scale, say several tens of cows, and family based farms out of business? Around the world, in almost all countries, cow farming is family based production. This include almost all countries named right above. In those countries, family based small-scale cow farms have been proven to be the most efficient model in cow milk production. This is especially true if we count job creating, smallholder farmers' substantial needs and welfare, environmental impacts, and sustainable development, etc. into consideration. But, in China, a country which has more than thousands times more rural population than in these developed countries, why do we have to force these smallholders out of business in cow farming?

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Part II

2015 SDDDC Chinese projects

Chapter 4 2015-R1 Longevity dairy cows

Research on Cow Longevity and Primary Reasons for Culling in China Dairy Farm with more than 100 Cows

4.1 About Principle Investigator

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Jun2006-Sept 2006	Exchange Student Dairy Science Department, South Dakota State University. USA
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Field of expertise

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Scientific publications are available at:

Http://cast1.cau.edu.cn/art/2015/8/11/art_19148_389853.html

4.2 Background and objectives of the study:

Recently, cow longevity attracted more attention in dairy industry in the world. More and more researchers try to find the correlations between risk factors and cow longevity, culling rate, from several aspects, such as genetic, breeding, reproduction, nutrition and farm management are related to cow longevity, in order to develop corresponding improvement and adversely affecting the cow longevity and farms' profit. Compared with 2014, the number of dairy cows in China fell by 1.3 million, 8.7%, which is the greatest reduce in a decade. Compared with developed countries, the statistic of cow longevity and culling is still in blank stage in China. There were some researches related just focusing on some specific farm or district, which were hardly to show the real situation in china dairy industry. This research was aimed to show the real situation of cow longevity in china dairy farm and primary culling reasons.

Through farm visiting and questionnaire collecting, this research altogether collected data of 355,000 cows from 100 farms in total, from Northeast China (Heilongjiang), North China (Beijing, Hebei, Tianjin, Inner Mongolia, Shanxi), East China (Shanghai, Anhui, Shandong), Northwest China(Ningxia) and parts of the South of China (Guangdong, Hubei), eliminated from 2013 to 2015, which can represent 909,000 cows, 10.4% of all cows in China.

Objective:

1. The general situation of cow longevity in China dairy farms with more than 100 cows
2. Analyse the main culling reasons and risk factors
3. Practical recommendations for farm

4.3 Main report of the research

4.3.1 General situation of cow longevity

Table 4-1 shows the general situation of farms in survey and culling rate of culling cows. From 2013 to 2015, the average herd size is increasing, which reflected the process of china dairy farms from small farmers to large-scale farms. The average culling rate in 2014 is the lowest and the percentage of 2015 is highest, about 30.4%.

Table 4-1 General information of the data

Year	No. Of cows	No. Of farms	Average herd size	No. Of culls	Average culling rate(%/yr)
2013	107,149	72	1488	26,510	24.7
2014	127,712	90	1419	29,274	22.9
2015	118,457	78	1518	36,061	30.4

Table 4-2 the average lifespan, productive lifetime and parity of culls in 2013-2015

Year	Lifetime(d)	Averageage(y)	Productiveliftetime(y)	Averageparity
2013	1616	4.4	2.1	2.5
2014	1749	4.8	2.3	2.7
2015	1829	5.0	2.5	2.9

Table 4-2 shows that the average lifespan, the average productive lifetime and the average parity all increased year by year. That may related to the increasing proportion of large scale dairy farms. The unified management of high level is beneficial to the improvement of the cow longevity.

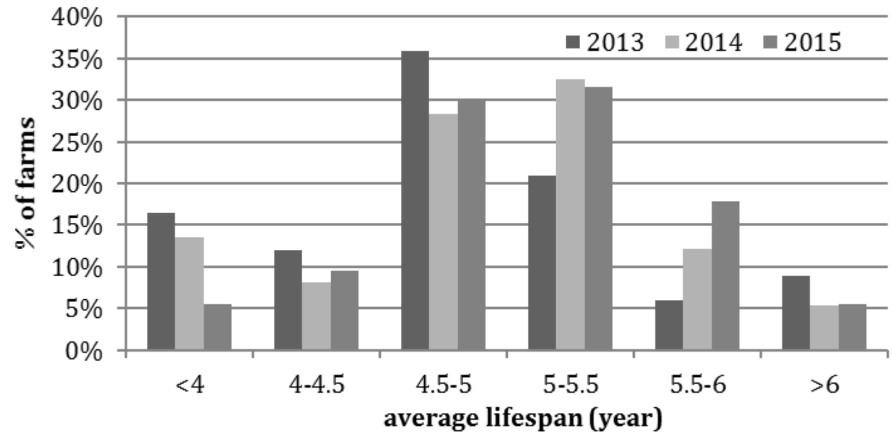

Figure 4-1 Distribution of farms across lifespan classes (2013-2015)

Figure 4-1 shows that less than 10% of farms have longevity more than 6 years. In 2013, 2014 and 2015, the proportions of these good performance farms are 9.0%, 5.4% and 5.5%, respectively. While more than 15% of farms have a longevity less than 4.5 years and the proportions in three years are28.4%，21.6% and 15.1%.

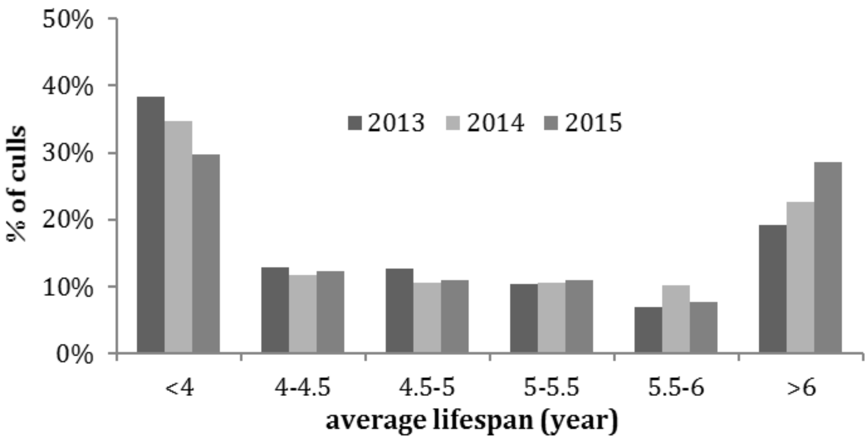

Figure 4-2 Distribution of culls across lifespan classes (2013-2015)

Combine figure 4-1 and figure 4-2, we found that most farm have a longevity between 4.5 and 6, but the average lifespan of most culls are lower than 4 years and higher than 6 years. In addition, it can be observed visually that as time, the average lifespan of farms became longer and the distribution of culls was changed. Compared with 16.4% farms in 2013, only 5.5% farms' average lifespan was lower than 4. The proportion of farms with average lifespan over 5 years increased from 35.8% (2013) to 54.8% (2015). About 38.3% of culls lived shorter than 4 years in 2013 while the proportion declined to 29.8%. The proportion of culls lived longer than 6 increased from 19.1% (2013) to 28.6% (2015).

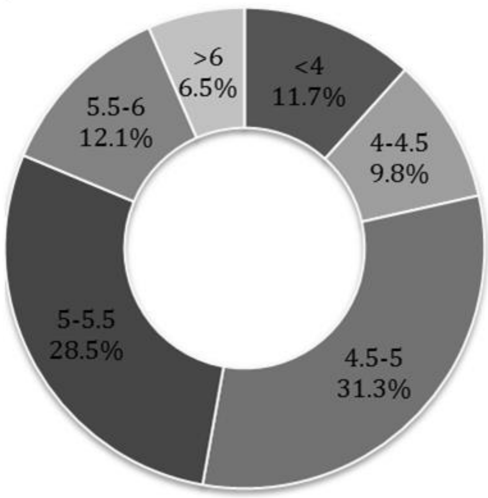

Figure 4-3 Distribution of all the farms across lifespan classes

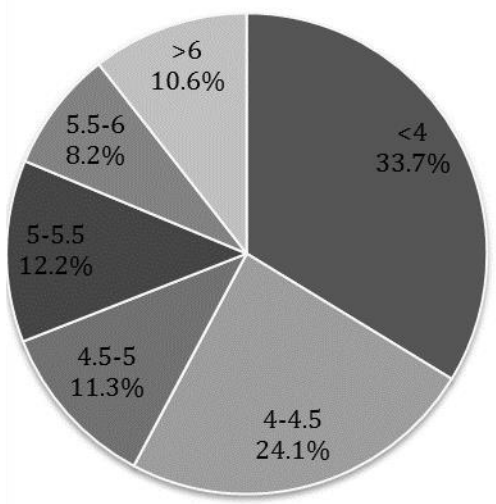

Figure 4-4 Distribution of 86171 culls across lifespan classes

In figure 4-3 and 4-4, 71.9% farms located in the range of 4.5-6 years and only 31.7% culls located in the same range, which means more culls left herd before 4.5 in the other 29.1% farms.

These 4 figures show quite some potential to improve cow longevity in China, and apparently indicate the improvement in China cow longevity. As time goes by, farmers and farm managers started to pay more attention to cow longevity and make some improvement on it to reduce culling in lower parity.

According to the parity record and herd size of 90485 culls in the survey farms, the average parity is 2.7. Figure 4-5 shows 72% culls were culled in the first 3 parities and the proportion of the 2nd parity is the highest, about 26.2%. Observing the distribution in 2013, 2014 and 2015, the most culls all happened in the 2nd parity, but the proportions of the first and second parity were declined. Compared with 2013 and 2014, culls left the herd after parity 4 increased apparently. The proportion of culling in the first three parities is 76.5%, 72.5% and 68.3%, respectively in three years, which shows a declining trend.

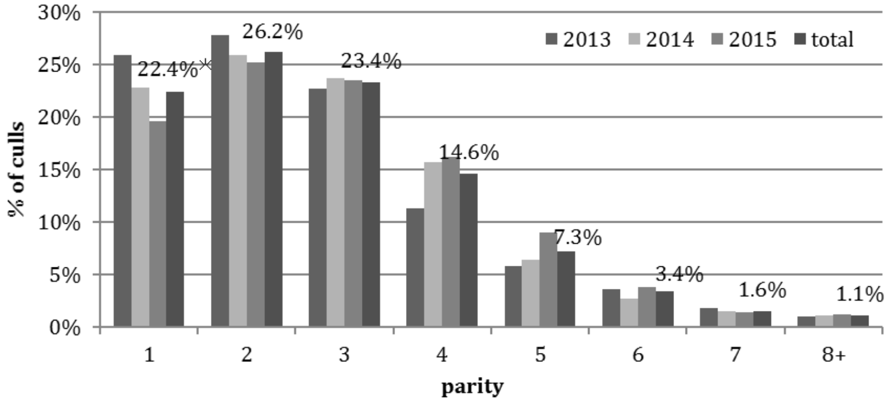

Figure 4-5 Distribution of culls across parity classes

*Data of distribution of 90485culls across parity classes in three years

There are many reasons for the high culling rate of the 1st parity cows. Firstly, the age of first service is too early. Secondly, the feed of fresh cow is over nutrition， which made the calve so big that hurt the birth canal. The high culling rate in early parity cows also reflects the management problems in feeding, breeding and diseases prevention. But the data also shows that the situation is becoming better.

4.3.2 Main culling reasons

Culling reasons of dairy cows divided by involuntarily and voluntarily culling reasons and most involuntarily culling due to reproduction problems and health disorders. There are kinds of diseases of dairy cow, in this research we divided all the disease into 7 parts, digestive disorder, udder disease, respiratory system disease, hoof disease, cycle system disease and nerve system disease. And the voluntarily culling divided into low production, sale and other (including old, bad body condition, bad temperament, et al.).

Figure 4-6 shows that more than 74% culls left the herds due to health diseases or reproduction problems. Among these culling reasons, the most-frequent primary culling reasons were "Repro"(infertility or reproduction problems), "Diges" (digestive system disorders and metabolic disorders), and "Udder" (udder-related disorders, such as mastitis and teat injuries), which accounted, respectively, for 20.9%, 20.7% and 13.7% of total culls. Hoof diseases was also important, accounted for 8.5%.

However, a larger percentage of cows (8.4%) were removed from the herd due to "Uno" (unknown or unspecified) culling reasons. This may indicate missing data recording in cow files, particularly in some farms in China. There have been studies trying to ascertain why cows die on farm and from which diseases, but the information gathering is hindered by inaccurate and inconsistent data entry.

In addition, only 11.4% were voluntarily culled cows and the highest voluntary or "selected" reason for culling is "Low Pro" (Low milk production) at 8.6%. That might show us farmers hardly cull their cows, unless the cows can't bring benefits any more.

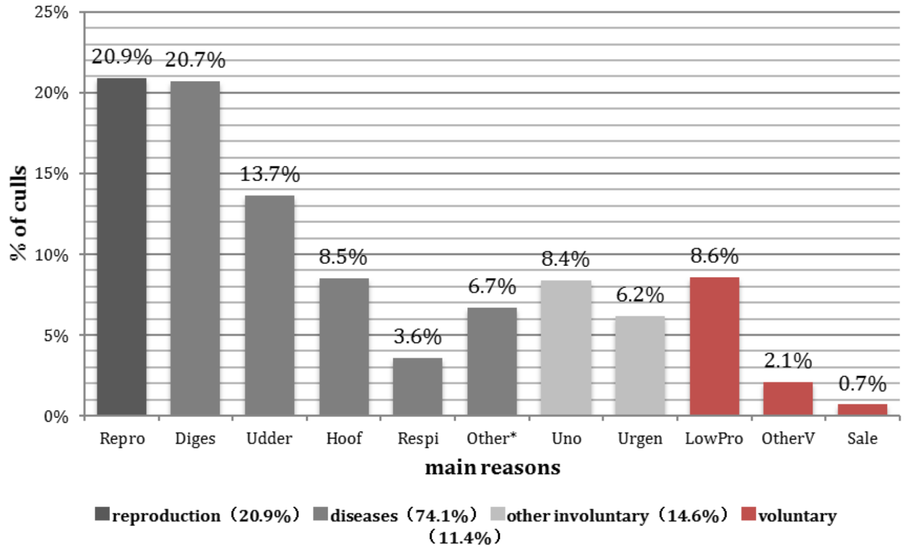

Figure 4-6 Distribution of 91845 culls in different culling reasons

* other diseases include cycle system disease, nerve system disease and other disease with

4.3.3 Culling reasons in different lactating days

There have been many studies suggested that culling rate for cows in earlier lactating days is very high. Figure 4-7 shows that about 27% culling cows culled before the first 60 days in lactating and the proportion is highest. Feed changing, calving and group turning are all stress for transition cows. If there are problems in these cows, the culling rate for cows in earlier lactating days will be always high. Culling also often occurs after 450 days in lactating days. In this stage, the main reason of culling is reproduction problems.

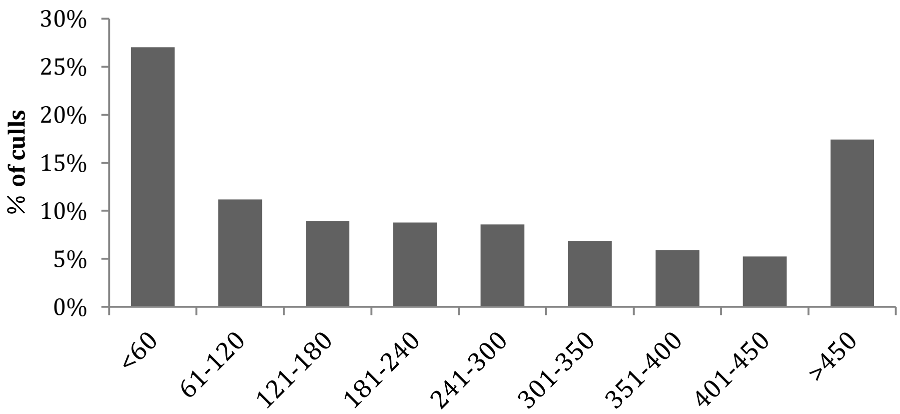

Figure 4-7 Distribution of 56120 culls across DIM(days in milking) classes

The figure 4-8 to figure 4-11 shows the distribution of culls across DIM classes in different culling reasons.

Figure 4-8 shows that more than 60% of culling cows removed by reproduction problems left herd after 350 days in milking. And 11.9% of cows with reproduction problems were removed before 60 days in milking.

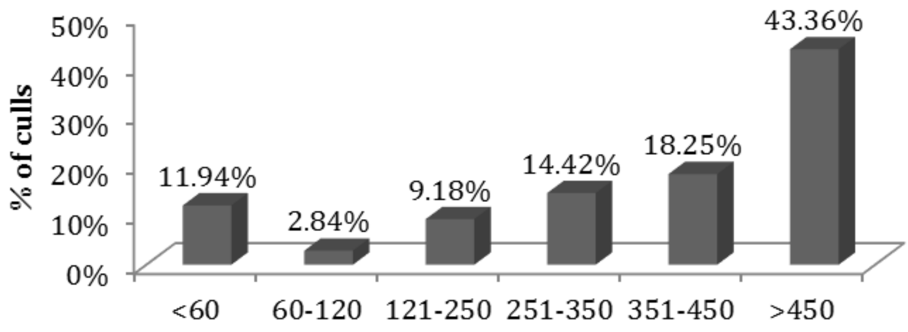

Figure 4-8 Distribution of culls with reproduction problems across DIM classes

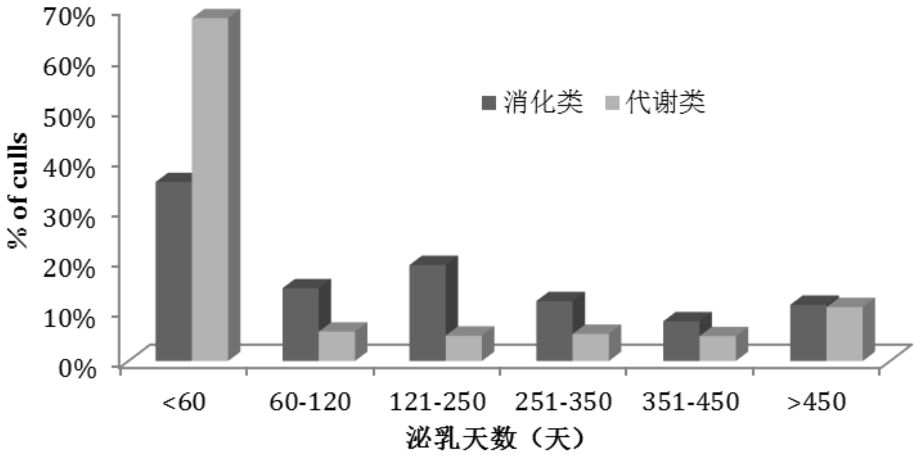

Figure 4-9 Distribution of culls with digestive system diseases and metabolic diseases across DIM classes

Figure 4-9 shows that 35.5% cows with digestive diseases culled before 60 days in milking and 19.1% culled after 350d. While 68% cows with metabolic diseases culled before 60 days in milking and 15.7% culled after 350d. Metabolic diseases always happened before 60 days in milking, which might due to the changing ration after calving and kinds of stress.

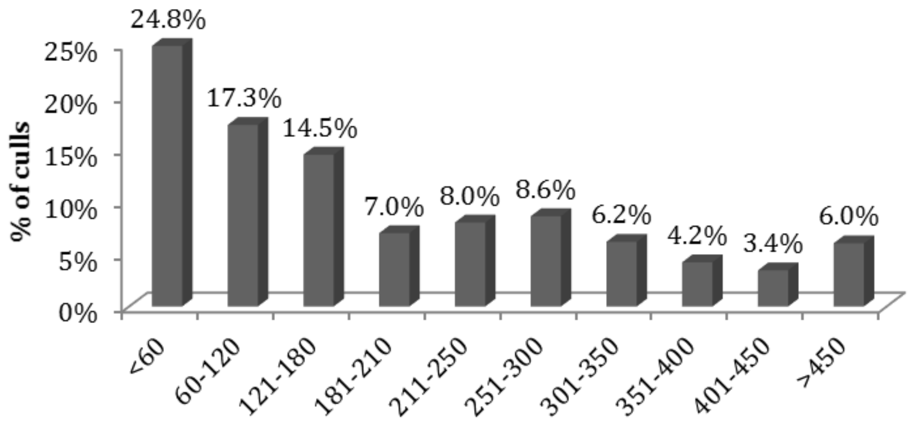

Figure4-10 Distribution of culls with udder diseases across DIM classes

Udder diseases are influenced by many factors, including the environment in barn and milking parlor, milking equipment and hygiene management, and operation of milking and dry milk program, etc. Figure 4-10 shows that most cows were eliminated within 180 days after calving, especially within 60 days, which may be due to problems in dry milk program and dry milk period management.

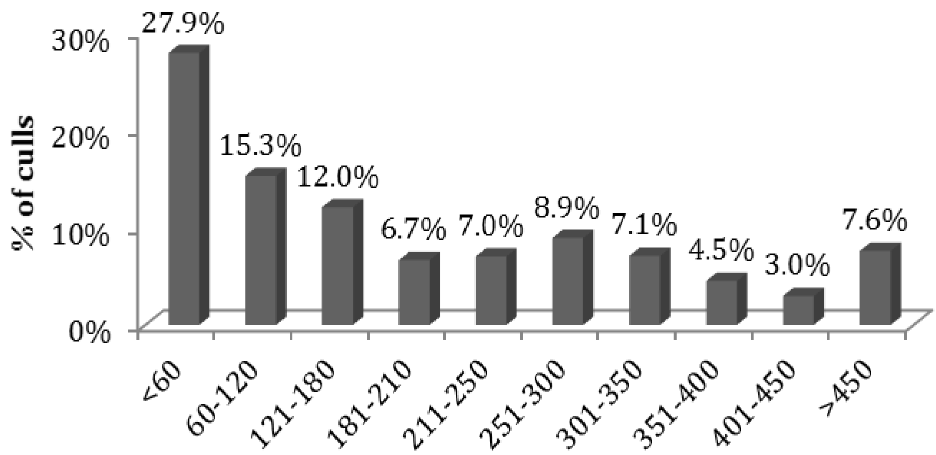

Figure 4-11 Distribution of culls with hoof diseases across DIM classes

Figure 4-11 shows that 27.9% cows with hoof diseases culled before 60 days in milking and 15.1％ culled after 350 days. Hoof diseases affected by various factors, physical factors such as the hard ground, uncomfortable bed, biological factors such as manure pile, disinfection not in time, and management factors such as unreasonable diet, trimming not in time, will lead to cows' hoof disease.

4.3.4 Culling reasons in different parities

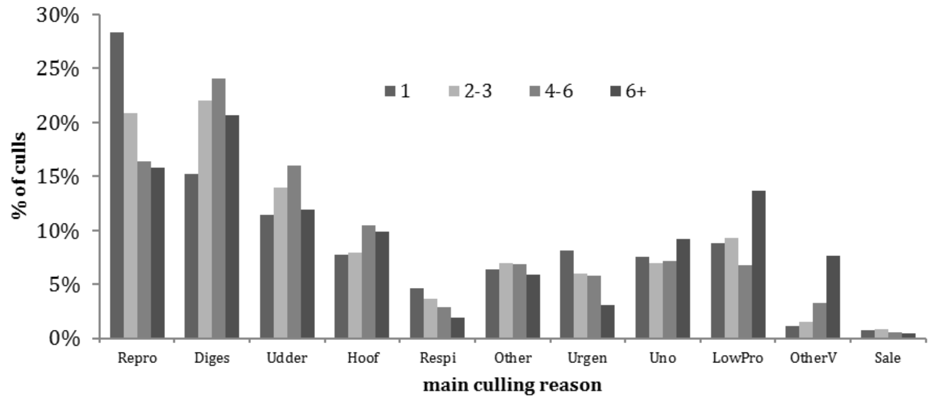

Figure 4-12 Distribution of different culling reasons of 90485 culls across parity ranges classes

Figure 4-12 shows that in each parity level, the main culling reasons are still reproduction problems, digestive system diseases and udder diseases and hoof diseases. However, in cows culled after parity 6, 21.8% of culls due to voluntary reasons and the low milk production accounted for 13.7%. The proportion of low production and other voluntary culling reasons both increased gradually as the parity rise. By contrast, in the first parity, up to 28.4% due to reproduction problems were culled, which was 7.5% more than the proportion of reproduction reasons in all culling reasons in the whole group. As the parity rise, the proportion of culls with reproduction problems gradually reduced. In addition, the proportion of culls by the digestive and metabolic diseases, udder diseases and hoof diseases was highest in the 4 to 6 parity, more than 50%. While in the first parity, the proportion of cows eliminated due to the three categories of culling reasons was less than 35%.

4.3.5 Culling reasons in different milk production

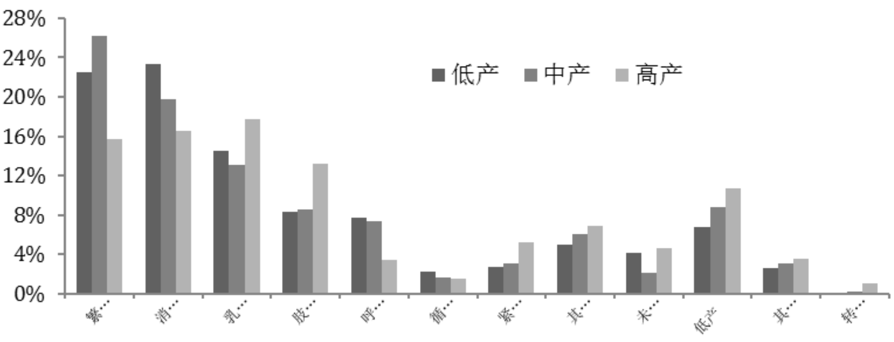

Figure 4-13 Distribution of different culling reasons of cows across milk yield levels classes

All culling cows divided into three average milk yield levels, respectively are low yield (< 10.4 kg/day), middle (10.4 kg/day - 22.5 kg/day), and high yield (> 22.5 kg/day).

Figure 4-13 shows that no matter the milk yield in high or low level, reproduction problems, digestive and metabolic diseases and udder diseases are still the main culling reasons. But in low milk yield level, cow culled by more digestive and metabolic diseases, while in middle level, the proportion of reproductive problems obviously increased.

In the high milk yield level, ratio of culls with udder diseases was the highest and the ratios of culls due to hoof diseases, emergency and urgency, low milk production are obviously increased.

Though the milk production of this part of the cows was in the medium level in the herd, but the udder diseases and hoof diseases is likely to require using antibiotics in the treatment process, which not only affects the normal milking, the milk is also can not for sale. For the farmers or managers, these cows don't have economic value, so they will be selectively eliminated. In addition, once the milk yield of high productive dairy cows decrease, even if there is no obvious symptom, they were also more likely to be culled.

4.3.6 Recommendations

In China, there is almost no attention to cow longevity. Farmers and farm managers are prone to put all their reflection and energy on how to make profits from cows and how to reach milk production targets. So the first thing we may do is communicating farmers and farm managers the importance of increasing longevity of cows.

Surveys show that the major reasons for culling are reproduction failure, mastitis, and lameness. Our data also show the similar conclusion that reproduction disorders, udder-related disorders, digestive system disorders and hoof diseases are assured known causes of culling in China, accounting for 68% of all culls. For most average herds these are the areas requiring attention to improve herd longevity.

Before, we have mentioned that milk production influences farm managers' decisions. In fact, milk production is intimately connected to fertility and udder health. Hoof health and rumen health will also indirectly affect milk production. If a cow does not breed back and calve again, she will gradually (or suddenly) drop in production to levels beneath profitability. A mastitis cow produces less milk, if subclinical, or goes into the hospital group and incurs additional medical treatment and labor costs if clinical. Severe or chronic infections are costly.

If we want to increase cow longevity, we should improve the health and welfare of dairy cattle and minimize kinds of diseases of our cows.

The first step in improving longevity within a herd is to establish the current position by benchmarking key figures for the herd against group averages. Once a factor has been measured, it can be managed and priority areas can be identified for attention. Prepare a list of all culled cows in the last year. For each one identify the reason for leaving from the list. Then calculate some following indexes, such as:

1. **Culling rate**

Take the total number of culls over the 12-month period and divide by the rolling average herd size for the same period.

2. The percentages leaving for each of the main culling reasons

Calculated by taking the totals for each reason divided by the total number of culls.

3. Average lactation age (average parity)

Calculated using the latest set of records for the herd.

4. Involuntary or forced culling rate

The total number of culling cows for an involuntary reason divided by the rolling average herd size.

Using the calculated figures for the herd and comparing data with group averages, a farmer will find the relative situation. If this relative position is suboptimal, then he can select a herd strategy to achieve his optimal position (reduce overall culling rate or reduce the level of a specific reason). All the problems cannot be fixed at once. So we should draw up a priority action list and address the biggest problems first.

Identify the major reasons cows are getting culled and generate possible solutions. If all culling reasons are higher than expectation, start from focusing on one or two to determine causes and begin action plans to correct the problems. Further investigation is needed once a category has been selected to better understand reasons for culling and generate possible solutions.In addition, if the total involuntary culling rate is greater than average or the farm target, or the involuntary culls are over 65% of all culls, there is opportunity to improve it. We can set an achievable guideline. However, the goal should be to minimize the involuntary cull rate.

For example, cows leaving the herd when less than 30 days in milk (DIM) usually are cows that have died or have serious metabolic or infectious disease problems at calving. It is important to distinguish between cows that are culled and cows that die. Analyse the records to determine early lactation culling cows and the broad categories causing cows to leave.The farmer should develop guidelines to support decisions about culling, especially for decisions in early stage of lactation. Farms also need todevelop a farm specific action plan and set up a monitoring plan. Work with the appropriate team of advisors and employees to develop an action plan based on your on-farm investigations and also some key monitors to determine if your plan is working. Make modifications to the plan if it does not deliver the expected results.

Many researches were about the main risk factors for involuntarily culling reasons and built economic models. However, how to let producers approved to accept the knowledge through the best management to improve the cow health and welfare is still an ongoing challenge.We called for the establishment of a clear standard of animal welfare and clear standards of digital, allowing farmers to clear what is their management level, in order to help them overcome these challenges.

4.4 Conclusion

1.The average yearly culling rate of China dairy cows in herds with more than 100 cows was calculated, which were 24.7%, 22.9% and 30.4%, respectively from 2013 to 2015. The average lifespan was accounted for 1616d、1749 and 1829d, while the productive lifetime was accounted for 747d、847d and 916d, respectively. The average parity at culling were about 2.5, 2.7, and 2.9.

In these 3 years, Dairy farming in our country is still in the transition to a intensive large-scale dairy farm, with the average herd size increasing and the ratio of farms with more than 100 cows increasing. Therefore, China dairy farms are equivalent to keeping expanding the scale. In addition, the farm operators and managers also gradually realized the importance of the cow longevity.In the daily management,they consciously to improve cow welfare and health, so the research data shows that the cow longevity was increasing year by year.At the same time, the increasing also reflects greatly improving space and potential in China dairy cow longevity.

2. Reproductive problems is the most serious accounted for 20.9% of the total number of obsolete, followed by digestive diseases, accounting for 20.7%, udder diseases (13.7%), hoof diseases (8.5%) and unknown reason (8.4%).

More than 74% of culls were culled because of kinds of diseases or reproduction problems.The voluntary culling proportionwas much less than other countries, accounted for 11.4%. And the highest voluntary or "selected" reason for culling is Low milk production at 8.6%, which might reflect that farmers always focus on profit and milk production. In addition,a larger percentage of cows (8.4%) were removed from the herd due to unknown or unspecifiedculling reasons, which indicate the omissions and contempt of data recording in China dairy farms.

3. Most Culling occurs before 60 days or after 450 days in milking, which ratio is about 27% and 22.6% respectively. Cows with reproduction problems and respiratory system diseases usually culled at early parities (1-3 parity), while cows with digestive system disorders, metabolic diseases, hoof diseases and udder diseases often culled at peak lactations (3-6 parity). More cows with reproductionproblems and digestivesystem disorders were low production cows while cows with high milk production often culled by udder diseases and hoof diseases. Therefore, farm shouldfocus on strengthening the management of transition cows, pay attention to the cow welfare, in order to reducing involuntary culling proportion.

4.5 Appendix

Longevity and culling rate: how to improve?

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4.5.1 The importance of longevity and culling rate

Animal health problems in dairy herds create extra costs, reduce milk production and will lead to high involuntary culling rates. In the Netherlands as well as in China dairy experts consider disease incidence rates and suboptimal culling rates as indicators of bottlenecks in dairy farm management. Improving health and animal welfare will result in longer living cows and this is why high longevity and lifetime production are seen as indicators for good dairy farm management. Improvement of this longevity is associated with lower culling rates.

Health problems are not only causing loss of profit but also disturb the workflow on the farm. Sick cows have to be treated and need extra attention until recovery. They will also cause infectious risks for the rest of the herd and should therefore be kept in isolation to avoid contamination.

The vision of farmers and consultants on longevity and culling is strongly influenced by views within the dairy industry and by the state of knowledge on animal health within the sector. These points are the reason that both topics evoke different associations in China and in the Netherlands. Table 4-1 lists some of these cultural differences.

Table 4-1 Differences about longevity aspects between China and the Netherlands

Aspect	China	Netherlands
Statistics	Start with pilot to collect data about culling rates and culling reasons	National statistics available about, longevity, lifetime production, culling rates and culling reasons
Available young stock	Shortage of young stock. Extra supply of heifers from New-Zealand and Australia	Farmers rear more young stock than needed for replacement. Part is exported outside EU.
Determining factors for longevity	Shortage of young stock and high milk prices stimulate farmers to keep suboptimal producing cows longer	High incidences of fertility, hoof and udder problems are constraining longevity
Longevity is indicator for farm management quality	Longevity became an important indicator for farm management quality in most large-scale dairy farms of dairy groups in recent years, while few individual farms take it as one of the important indexes.	Yes, this is the general opinion
Vision society	Animal welfare is becoming a public concern and more and more farm managers believe that cow welfare related with production efficiency.	Society desires good cow care resulting in more animal welfare and longer living cows
Financial incentives to increase longevity	In general: increasing longevity is not always expected to be profitable. It is more associated with lack of young stock.	In general: increasing longevity is considered to be profitable for the farmer Some dairy processors pay bonus on milk price to farmers with older cows

The Netherlands have a long tradition in aiming at high lifetime production of cows. For many decades cows that pass the limit of 100,000 kg milk or 10,000 kg fat and protein are honoured at a party on the farm. And of course the farmer who cared for the cow, is part of this tribute. In the last five years longevity receives extra attention from society because it is seen as an indicator of good care for cows. This is why the dairy sector is now aiming at increasing longevity by half a year during the period until 2020. This goal is part of the sustainability program of the united Dutch dairy companies and dairy farmer unions.

The goal of this paper is to present the results and experiences of collaborative work on longevity and culling rate on dairy farms. In 2015 Wageningen UR Livestock Research and China Agricultural University investigated the present situation on longevity and culling in both countries. Wageningen UR livestock Research summarized the efforts done in the Netherlands to come to an improvement program on longevity. China Agricultural University collected data of 81 farms with 113,367 dairy cows aiming at getting a better insight into culling practices on Chinese dairy farms.

4.5.2 Present situation in the Netherlands

The average age at culling (also defined as longevity) of Dutch dairy cows is 5.8 years[1]. In the last five years this figure has been quite stable. As mentioned before the Dutch dairy sector has the ambitious goal to increase it by six months in the period until 2020. Research showed that there is much variation between farms for this trait. The 25% farms with highest longevity have an average longevity of 7.1 years, whilst the 25% farms with lowest longevity have an average longevity of 4.9 years. This variation shows quite some potential to improve longevity.

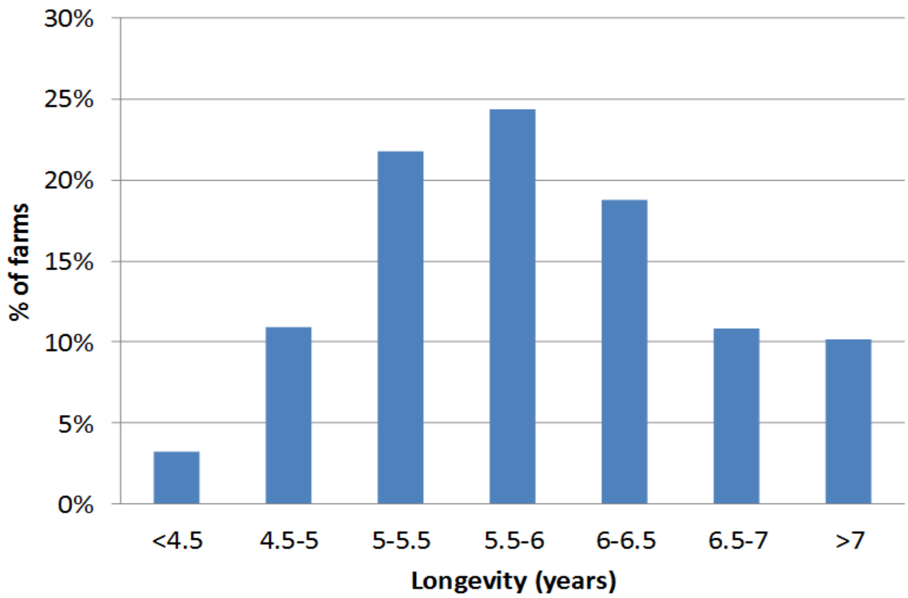

Figure 4-14 Distribution of Dutch farms across longevity classes[2]

Figure 4-14 shows the division of culls by parity for Dutch cows on farms where culling reasons were recorded. The proportion of herds that record culling reasons has steadily grown in the last decade. In 2012 it was increased until 32% of all farms participating. The pattern shown by the bars in figure 2 is strongly connected to longevity. If longevity increases, a larger part of the culls will take place in higher parity numbers.

Figure 4-15 shows the reasons for culling on Dutch farms. Fertility, cell count/mastitis and legs and claws are the most frequently mentioned reasons for culling. The fourth reason 'fattening' is a kind of indirect reason for culling. Farmers will usually only fatten cows if they have decided to cull the cow at a later stage but like to combine milk production with fattening in the remaining productive life of the

[1],CRV, 2015
[2] Zijlstra et al., 2013 (data of Dutch farms during the period 2006 until 2012)

cow. The underlying reason for this decision can be e.g. infertility or disease incidences. Fattening is a kind of voluntary culling with an involuntary underlying reason. The same can be more or less true for other voluntary culling reasons like excess cows, low production and old age. This combined voluntary and involuntary culling reasons show that the differences between these two main categories are not easy to mark. However, Figure 4-16 shows very clearly that that fertility, mastitis, claws and miscellaneous health problems are the main reasons for involuntary culling on Dutch farms.

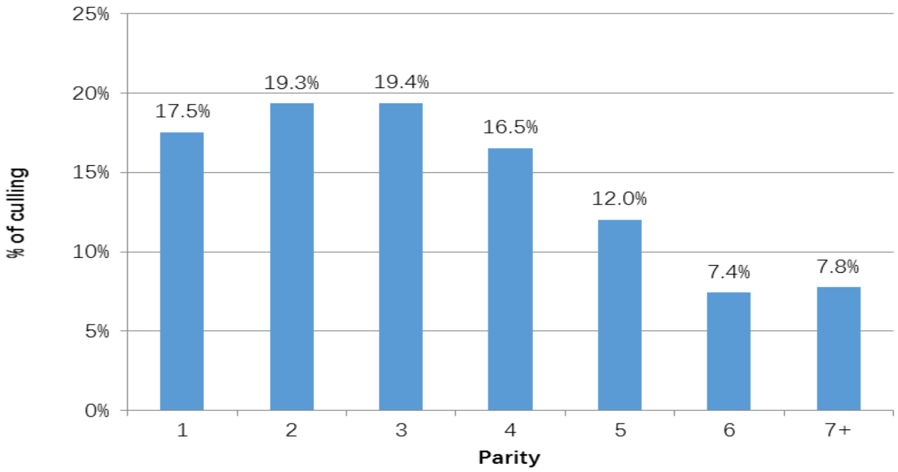

Figure 4-15 Percentage of culls by parity[3]

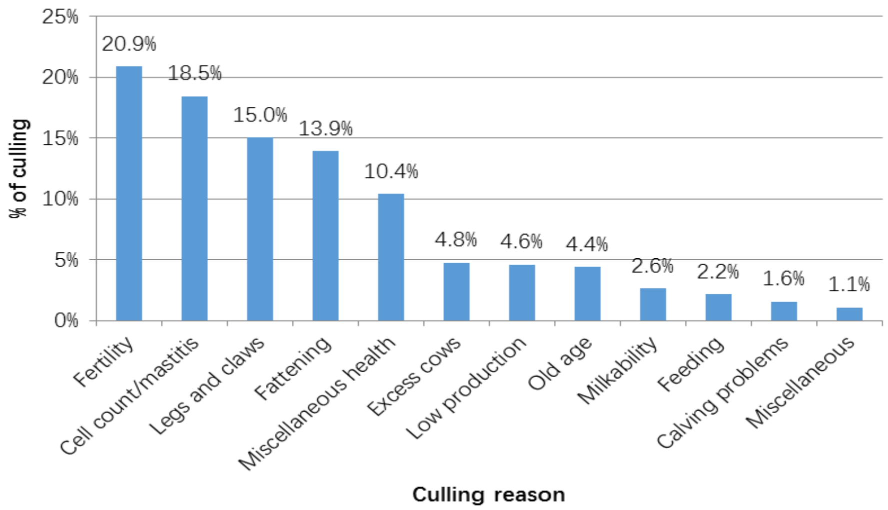

Figure 4-16 Reasons for culling[3]

4.5.3 Present situation in China

As mentioned before China Agricultural University collected data from 81 farms with 113,253 dairy cows (including dry and lactating cows) in total. The average herd size of these farms was 1398 cows.

Actually, the study comprised two main parts:

[3] Based on CRV data from 284,864 cows with minimal 87.5% Holstein breed, that were culled in the years 2007 until 2012.

1) Individual cull information (farm visits and questionnaire)

2) Group dairy farm data

Firstly, participating dairy farms noted the reasons for culling of every cow that left the herd over a twelve-month period, starting in 2013. Secondly, these culling records provided primary culling reasons for each cow leaving the herd, resulting in a list of 50 culling reasons. Thirdly, each participating herd was sent a questionnaire asking for specific and detailed information on the management system of their herd. The questionnaire asked for details about the herd management system including fertility management, herd replacements, housing, milking, labour, and nutritional aspects. Table 4-2 shows a summary of the general statistics of the participating farms.

Table 4-2 General statistics for the provisional data in 2014

Total number of cows	113,253
Number of herds	81
Average herd size	1,398
Total number of cullings	26,431
Culling rate (%/year)	23.3%

Table 4-3 Number of farms and cows by different herd size (2014)

Range of herd size	No. of farms	No. of cows	No. of culled cows
>2000	16	72,069	15,557
1000-2000	13	17,001	3,984
500-1000	19	13,191	3,697
100-500	33	10,993	3,193
Total	81	113,253	26,431

Among these farms, 31 farms have lower culling rate than 23.3%. 76 of the farms recorded the parity of 25,917 culled cows and 65 farms recorded both the birth date and cull date for 23,881 cows. The average lifespan of culls is 4.9 years and the average productive life of these dairy cows is 2.7 years. Among the 65 farms, the 25% best performing farms have an average longevity of 5.6 years, while the 25% worst performing farms have an averaged longevity of 4.0 years.

Figure 4-17 shows that 6.2% of the 65 farms have a longevity of more than 6 years, while the cow longevity in 16.9% of these farms is lower than 4.5 years. 49.2% of the farms have a longevity of less than 5 years in figure 4-17, while figure 4-18 shows that more than 57% of culling cows leave the herd before they reach the age of 5 years old. This difference is caused by the larger average herd size of the farms in the two low longevity classes in figure 4-17. However, 22.5% of culling cows leave the herd after 6 years old.

In figure 4-19, the annual variation in the percentage of culling cows shows that more cows leave the herd after 6 years old and less cows were culled before the age of 4.5.

Figures 4-17 and 4-18 both show quite some potential to improve cow longevity in China, while figure 4-19, apparently, indicate the improvement in China cow longevity.

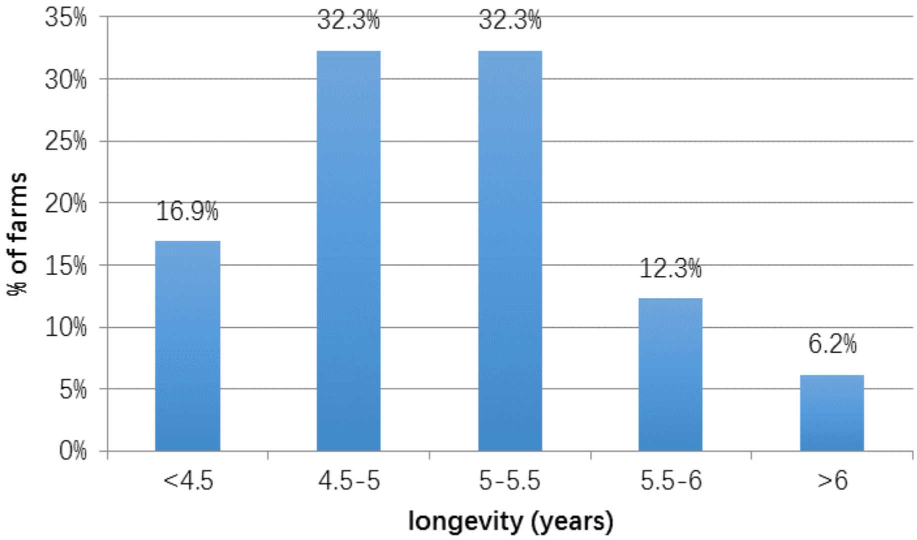

Figure 4-17 Distribution of 65 farms across longevity classes (2014)

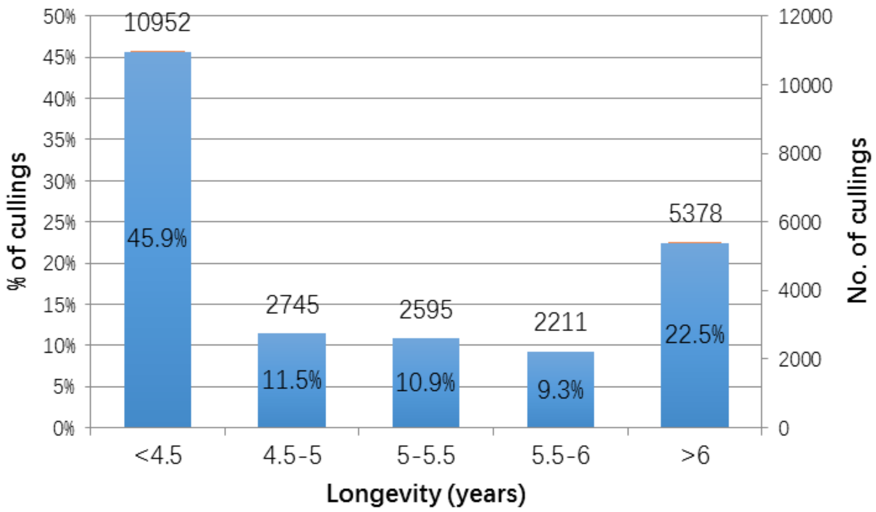

Figure 4-18 Distribution of 23,881 culling cows across longevity classes (2014)

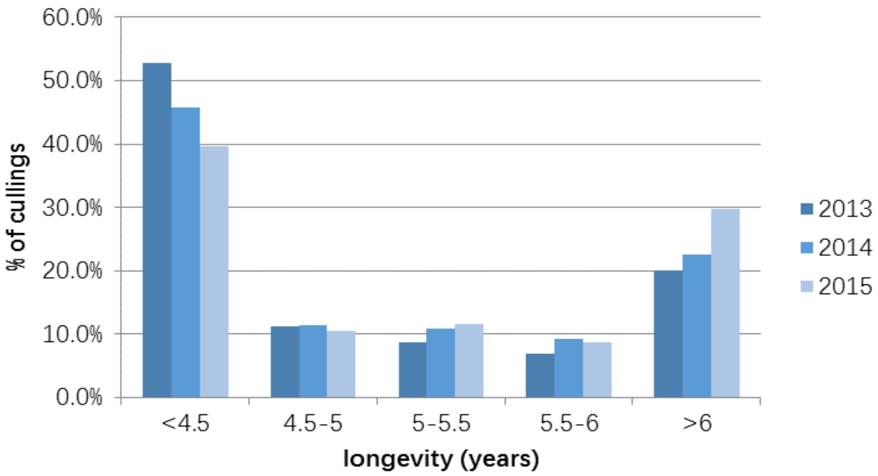

Figure 4-19 Distribution of culling cows across longevity classes in 3 years

Figure 4-20 shows the distribution of 26,341 culls by parity and there were 514 culling cows with no parity recording. And figure 4-21 shows that among the 25,917 culled cows, more than 73% of them are culled in the first 3 lactations and the highest percentage of cullings is in parity 2 with 26.3% of all cullings. This division of cullings about parity leads to an average parity of culling of 2.7.

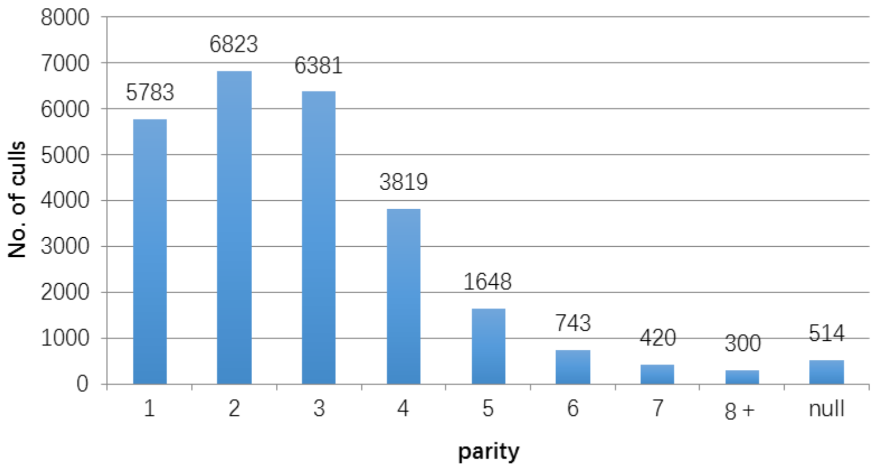

Figure 4-20 Number of all culls by parity (26,431 culls)

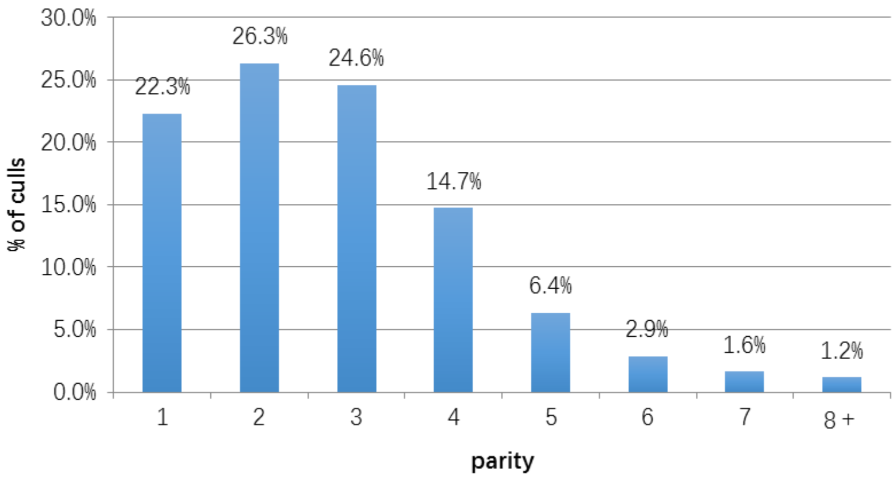

Figure 4-21 Percentage of all culls by parity (25,917 culls)

The most-frequent primary culling reasons were "Diges" (digestive system disorders and metabolic disorders), "Repro" (infertility or reproduction problems), and "Udder" (udder-related disorders, such as mastitis and teat injuries), which accounted, respectively, for 23.9%, 22.7% and 12.9% of total cullings. More than 81% of the cullings were declared in relation to health or reproductive disorders. Among these health related culling reasons, "Hoof" (hoof diseases) is also important to note, accounting for 7.3%.

However, a larger percentage of cows (4.1%) were removed from the herd due to "Uno" (unknown or unspecified) culling reasons. This may indicate missing data recording in cow files, particularly in some farms in China. There have been studies trying to ascertain why cows die on farm and from which diseases, but the information gathering is hindered by inaccurate and inconsistent data entry.

”Urg”(urgency)is also an important reason for culling. 4.1% of culled cows were sudden death or accidental injury, which exposed several problems in farm management.

Dairy cows, experiencing a disease or a reproductive disorder, are exposed to higher culling risks. This category of culls is usually designated as `involuntarily (or forced) culled cows', in contrast to all the other culls or sales, which are designated as `voluntarily (or selected) culled cows'. In Figure 4-22, only 8.83% were voluntarily culled cows and the highest voluntary or “selected” reason for culling is “MPro” (Low milk production) at 7.9%. That might show us farmers hardly cull their cows, unless the cows can’t bring benefits any more.

Possible reasons of fluctuation in culling rate may be the levels of milk production and milk and beef prices. Some farm managers suggest that these factors determine their culling decisions. So farmers may cull more cows in times of low milk production, low milk prices, and/or high beef prices. Some first results of our analysis show a negative relationship between milk price and culling rate. As the milk price drops, the culling rate increases. It means that farm managers tend to remove more cows from the herd in times of low milk price, due to unprofitable production.

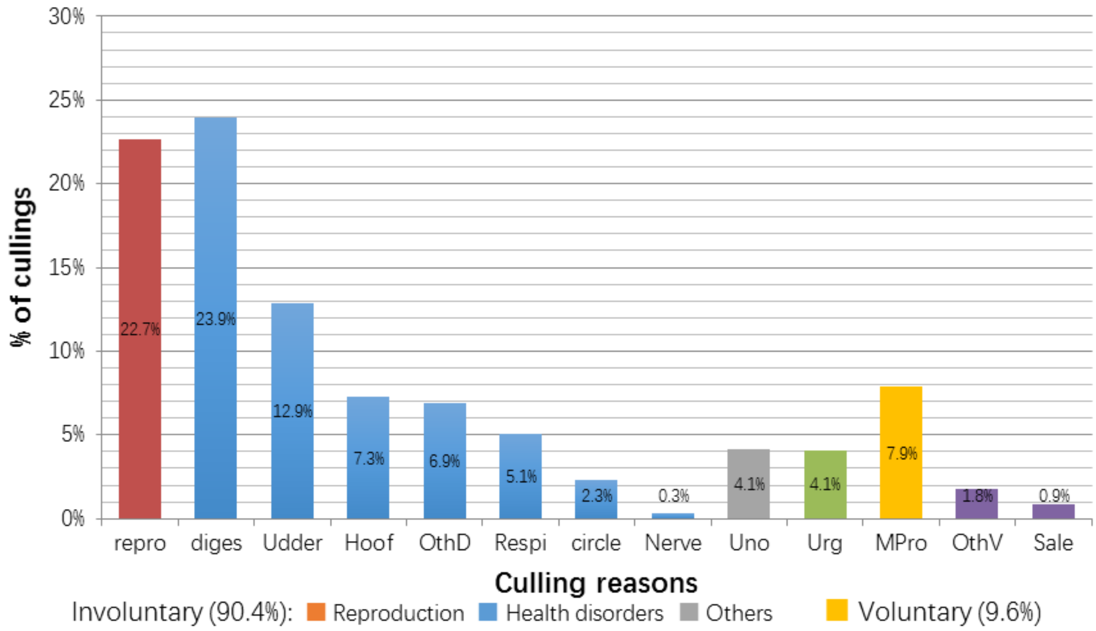

Figure 4-22 Reasons for culling (n = 25,920 cullings)

4. International differences in average productive life

Table 4-4 Productive life of dairy cows in some countries specialized in dairy production

Country	Average productive life*
New Zealand	4.2
United Kingdom	3.9
The Netherlands	3.7
Poland	3.3[4]
France	3.2[5]
China	2.7[6]
USA	2.7[7]
Canada	2.7[8]
Israel	2.5

*Productive life = time span between first calving and culling
Source: FAO[9]

The great variation in Table 4-4 between all these countries in which Holstein-Friesian-type cows dominate the dairy cow population, suggest that farming systems play a role in determining longevity. Apparently dairy cows live longer in countries with grass-based farming systems (in New Zealand, United Kingdom and the Netherlands large part of the farms have grass based farming systems). One may add that the average production per cow per day is usually also lower on farms with grass based farming systems compared to cows in confinement systems. This could also lead to the assumption that these cows in grass based farming systems might be exposed to less metabolic stress resulting in a longer productive life. In USA, Canada and Israel the average production per cow per day is relatively high compared to the other countries in the table.

4.5.4 Sector approach to improve longevity in the Netherlands

As part of its Sustainable Dairy Chain Agenda the Dutch dairy sector has explored the possibilities to increase longevity by improving health and welfare of dairy cattle. A qualitative expert approach to appoint bottlenecks and solutions resulted in four key proposals to stimulate dairy farmers to increase in longevity at farm level[10]:

1. Create awareness about the added value of longer living cows by demonstrating results of farms that have increased longevity in the past and by using a tool that can forecast the financial results of adaptations in farming practices.
2. Develop a Plan-Do-Check-Adjust (PDCA) approach and teach farmers how to work at farm level on their bottlenecks to increase animal health and welfare. The PDCA approach requires from farmers

[4] Analysis of longevity and reasons for culling high-yielding cows, Adam Oler et al., 2012
[5] Reasons for culling in French Holstein cows, H. Seegers and F. Beaudeau, 1998
[6] Preliminary results Ma Jiaying and Cao Zhijun, 2016
[7] USDA. Dairy statistics[DB/OL]. 2013. Available at http://future.aae.wisc.edu.
[8] Source: CanWest DHI and Valacta
[9] FAO, 2013. Available at http://faostat.fao.org/site/569/DesktopDefault.aspx?PageID=569#ancor
[10] Zijlstra et al., 2013

to appoint the performance indexes they want to improve and challenges them to define targets, actions and deadlines to achieve the desired higher level of animal health and welfare. Working this way is expected to increase longevity and the financial results of the farm.

3. Create incentives to stimulate farmers to work on longevity. These incentives can comprise: workshops or trainings, bonus milk price or extra permits or licenses for farmers with higher average longevity level of the herd.
4. Organize trainings about better labour organization to avoid that a high work load will result in suboptimal animal care.

Till so far the dairy sector has made a start with implementing proposals 2 and 3. The other proposals are not yet turned into actions. Proposal 2 has also led to the development of nine key themes to improve health and longevity: longevity, production, culling, transition management, udder health, fertility, claw health, rearing of young stock and use of antibiotics. For each of these themes experts have recommended performance indexes that can be combined to two one-page reports: one report for annual evaluation and another report for monthly monitoring and evaluation. The performance indexes for this monthly report are listed in Table 4-5.

Table 4-5 Proposal for performance indexes for monthly farm report to monitor and evaluate dairy herd performance

	Theme	Performance indexes (farm averages)
1	Production	- Milk production per cow (in real kg and in age and calving season corrected kg) - Fat and protein content - Urea content milk - Milk production, fat and protein content, age and calving season corrected milk for 5 groups (categorized for days in milk) - Idem for 3 groups categorized by parity (first calf, second calf and third calf and higer)
2	Transition management	- % cows with %fat / %protein > 1.25 - % cows scoring positive for ketose based on milk sample - % cows with %fat / %protein < 1 - % transition disease incidences
3	Udder health	- Cell count bulk tank - % mastitis incidences - % successfully treated during lactation - % New cows with increased cell count during lactation
4	Fertility	- Days open - Inseminations per cow
5	Claw health	- % incidendes of claw disorders
6	Rearing of young stock	- Age at first insemination - Inseminations per heifer - % diseases calves (during period 0-60 days)
7	Treatment with antibiotics	- Animal days-dosage-number

This report is made to provide farm managers with a quantified insight into the status of their farm for these themes. It also offers benchmarking possibilities by comparing farm figures with average performance indexes of peer groups. And in the Netherlands farmers, veterinarians and other consultants are also stimulated to formulate their own targets for some key performance indexes. These indexes are also valuable in the process to of the PDCA approach mentioned before. Improving indexes might require the introduction or adjustment of certain standard operating procedures that can support the right actions needed to move in the desired direction.

4.5.5 Recommendations to improve longevity in China

In China, there is almost no attention to cow longevity. Farmers and farm managers are prone to put all their reflection and energy on how to make profits from cows and how to reach milk production targets. So the first thing we may do is communicating farmers and farm managers the importance of increasing longevity of cows.

Surveys show that the major reasons for culling are reproduction failure, mastitis, and lameness. Our data also show the similar conclusion that reproduction disorders, udder-related disorders, digestive system disorders and hoof diseases are assured known causes of culling in China, accounting for 68% of all cullings. For most average herds these are the areas requiring attention to improve herd longevity.

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If we want to increase cow longevity, we should improve the health and welfare of dairy cattle and minimize kinds of diseases of our cows.

The first step in improving longevity within a herd is to establish the current position by benchmarking key figures for the herd against group averages. Once a factor has been measured, it can be managed and priority areas can be identified for attention. Prepare a list of all culled cows in the last year. For each one identify the reason for leaving from the list. Then calculate some following indexes, such as:

1. Culling rate

   Take the total number of cullings over the 12-month period and divide by the rolling average herd size for the same period.

2. The percentages leaving for each of the main culling reasons

   Calculated by taking the totals for each reason divided by the total number of culls.

3. Average lactation age (average parity)

   Calculated using the latest set of records for the herd.

4. Involuntary or forced culling rate

   The total number of cullings for an involuntary reason divided by the rolling average herd size.

Using the calculated figures for the herd and comparing data with group averages, a farmer will find the relative situation. If this relative position is suboptimal, then he can select a herd strategy to achieve his optimal position (reduce overall culling rate or reduce the level of a specific reason). All the problems cannot be fixed at once. Draw up a priority action list and address the biggest problems first:

- Identify the major reasons cows are getting culled and generate possible solutions. If all culling reasons are higher than expectation, start from focusing on one or two to determine causes and begin action plans to correct the problems. Further investigation is needed once a category has been selected to better understand reasons for culling and generate possible solutions
- If the total involuntary culling rate is greater than average, or the involuntary cullings are over 60%[11] of all cullings or if the involuntary culling rate is higher than the farm target, there is opportunity to improve it. We can set an achievable guideline. However, the goal should be to minimize the involuntary cull rate.
- Cows leaving the herd when less than 30 days in milk (DIM) usually are cows that have died or have serious metabolic or infectious disease problems at calving. It is important to distinguish between cows that are culled and cows that die. Analyse the records to determine early lactation cullings and the broad categories causing cows to leave.The farmer should develop guidelines to support decisions about culling, especially for decisions in early stage of lactation (e.g less than 100 DIM)
- Develop a farm specific action plan and set up a monitoring plan. Work with the appropriate team of advisors and employees to develop an action plan based on your on-farm investigations and also some key monitors to determine if your plan is working. Make modifications to the plan if it does not deliver the expected results.

4.5.6 Conclusions

1. Longevity as indicator

   In the Netherlands high longevity is considered as indicator for health and welfare of dairy cows. In China longevity is more connected to sufficient available young stock and milk price. In case of lack of young stock and high milk prices, longevity will increase.
2. Reasons for culling

   The most important culling reasons for dairy cows in both countries are almost the same. Reproduction problems, udder problems and hoof problems are in the top 4 in both countries. The difference in top 4 reasons are: digestive problems on place 2 in China and other (clustered) health problems on place 4 in the Netherlands.
3. Average productive life

[11] Uk M D C. Longevity - controlling culling to improve herd profitability.[J]. Publication - Milk Development Council, 2000.

Average productive life of dairy cows is 3.7 years in the Netherlands and first data of 19 Chinese dairy farms with an average herd size of 813 cows show an average productive life of 3.0 years. This productive life is exclusive the rearing period of about 2 years.

4. Recommendations to improve longevity

   In both countries we suggest to improve longevity by:

   a. Give the farmers clear insight into? their present longevity situation by benchmarking based on data about longevity, culling reasons and health problems.
   b. Make a priority list of targets on animal health and welfare that will support minimizing involuntary culling (action plan).
   c. Make a list of measures or best practices to adopt and apply them.
   d. Monitor results and modify the plan to make a better fit to the specific farm situation.

Acknowledgement

We thank Erwin Koenen and René van der Linde of CRV for sharing data about culling reasons in the Netherlands and for their comments on draft versions of this paper.

Chapter 5 2015-R2 Manure treatment under Chinese conditions

5.1. About Principle Investigator

Prof. Dr. DONG Renjie

China Agricultural University, Professor, Ph. D. Supervisor

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Professor Dong Renjie engaged in production and evaluation of biomass resources, artificial wetlands, indoor air quality monitoring and Africa agricultural development, biogas and biomass stove standardization since 1985, having achieved highly academic success. With outstanding achievements in the field of agricultural engineering and environmental engineering, Prof. Dong becomes the member and Secretary General in many famous conferences. Since 2005, he has been the chairman for Forum of Renewable Energy Promotion in Developing Countries (FREPDC) since 2005, also been the chairman of 2015International Composting Conference (Second Branch). Prof. Dong has published more than 200 academic papers so far, authorized 21 patents and carry out 30 projects. With abundant experience and leading interdisciplinary research teams, he has won lots of prizes in science and technology.

5.2 Objectives of the study

Sustainable Dairy Manure Management (SDMM) project deals with the most widely existing problem on dairy farm, to minimize pollution for dairy farms and surroundings, through appropriate and optimal integration of different manure handling technologies, including aerobic composting, anaerobic digestion, and effluent gases and liquids treatment. The overall goal of SDMM is to provide appropriate strategy and best technical recommendations for sustainable dairy manure treatment in China.

5.3 Main report of the research

5.3.1 Questionnaire Survey

According to many researches, most of cattle manure is treated in an Aerobic Compost (most as air drying) way after stockpiling, which is adopted at 143 dairy farms of 189 research sites in questionnaire. Apart from that, there are 37 dairy farms where survey data is absented after the feces separation. And only 9 farms are adopting the system of both manure separation and compost. According the questionnaires, most farms use mechanical collection system such as Scrapper and cleaning truck. And also, Artificial collection method is employed at 61 cattle farms, while only 18 farms artificial auxiliary machinery collection.

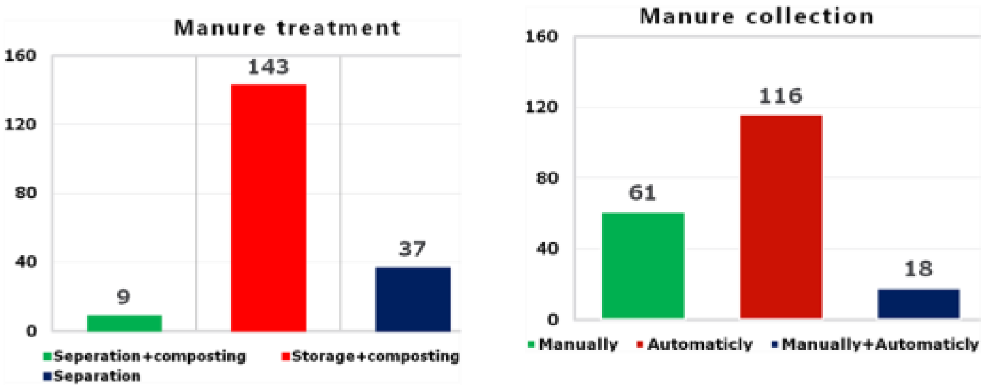

Figure 5-1 Manure treatment and collection in Questionnaire

5.3.2 Field investigation

We have been several dairy farms and got the fresh materials to catch a sight of the overall situation in China.

(1) Saibei Modern Farming Group is located in Zhangjiakou City, Hebei Province. On 19 September, 2015, researchers from CAU visited Saibei farm which has 12000 heads cows. The biogas fermentation engineering technology is adopted in farm to treat manure.

(2) YingBo Dairy Farming Co., Ltd. is a wholly-owned subsidiary of Bright Food Group Co., Ltd. It's a demonstration of modernization and holds 800 cows. Manure treatment center covers an area of 37500 m^2. Oxidation pond covers an area of 21500 m^2. There are two kinds of treatment measures, BRU (Bedding Recovery Unit) and biogas project. Figure outlines the operations that take place in manure treatment.

(3) Dairy industry is the dominant industry in Ningxia Hui Autonomous Region due to efficiently large-scale cattle breeding, four typical farms have been visited in Yinchuan City.

(4) ShenChi NongMu Co.,Ltd. in Tianjin holds a designed scale of 967 lactating cows, 249 cows (experiencing the period of milking stop), 241 calves, young cattle and bred cattle is 934 heads in total. There is about 91.6t dung output per day at farm and 61 m^3 sewage from cows.

(5) Datong Sifang Dairy Farm is jointly set up by the Datong Dairy Co. Ltd. and Yangjiayao village, which is the largest farm in Shanxi and bears the fame of national dairy industry technology system of Datong comprehensive experimental station (2011-2015). There are 4300 heads cattle. According to water quality, ecological recycling mode concerns “Scrapper+ Solid-liquid Separation+ Oxidation Pond”. The main units include “scrapper with water” collection system, “grid clearing and solid-liquid

separation equipment" pretreatment system, oxidation pond system to treat sewage, manure slag treatment system to obtain bedding materials.

(6) Qutou Farm in Beijing is a large cattle Farm. Through field investigation and sampling analysis, solid concentration of the manure sample in cowshed reaches 16.8%. After separation, the liquid manure was storage in a pond and the solid was further dried.

(7) Hebei Xinglong County Shuangfeng forestry and animal husbandry farm (Shuangfeng farm). The Recycled pattern at this farm is the cultivation with breeding. On the one hand, fertilizer produced from 300 high-quality dairy cattle feces to cultivate trees each year and ensure the basic nutrition of tree growth. On the other hand, deciduous trees every year also ensures 4 months of coarse fodder supplies for cattle. Through field investigation and sampling analysis, solid concentration reached 10.4%, dry dung cleaning way. At Shuangfeng farm, cowshed manure solids concentration is 10.4%, o analysis of solids concentration n beddings sampling is 15.0%. After centrifugal separation, solid concentration increases to 22.2%.

Figure 5-2 Summary of the manure treatment process in different farms

5.3.3 Sampling analysis

In order to reduce nutrient losses, legal nutrient application rates for nitrogen and phosphate have to be established and respected for different crops on different soils in different Chinese climate zones. Especially on sloping and bare land, manure runoff has to be prevented. Chemical analyses of the nutrient (N and P) contents of cattle slurry, anaerobic digester effluent, solid and liquid fractions and other manure products, is essential for the calculation of an accurate crop specific fertilization rate, the calculation of how much manure can be adequately utilized per mu (15 mu = 1 hectare). Insufficient fertilization rates will produce insufficient crop yields and excessive fertilization rates will cause nutrient losses to the environment. Unavoidable nitrogen losses following manure application (approx. 40-80 % of total N, depending on manure type and application technology) can be compensated with chemical nitrogen fertilizer.

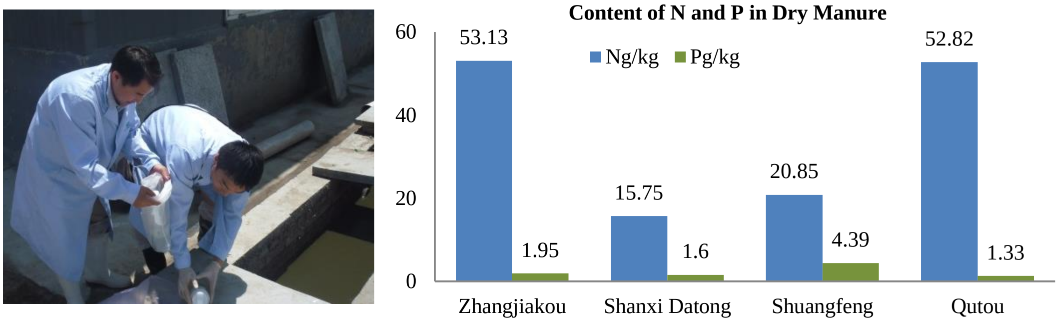

Figure 5-3 Manure sampling and some results of the analysis

5.3.4 Summarized patterns of manure treatment and utilization in China

(1) Cultivation with Breeding. Dry Manure Collection technology is adopted to get aerobic compost. Sewage is treated by anaerobic digestion or oxidation pool. If up the standard, manure and treated water could be used in agriculture land.

(2) Recycling. Water is saved through the total process. Sewage is conveyed by conduits. And rain sewage diversion and solid-liquid separation system are adopted to save water. Treated sewage is mainly used for flushing excrement groove or fences. Solid manure is utilized through compost, edible fungus matrix monk, bedding material preparation and fuels. This model is applicable to the economically developed areas with less planting around dairy field.

(3) Discharge on Standard. After anaerobic fermentation and aerobic treatment, if the Dairy wastewater could up to the national emission standards, then discharged to the environment or to urban sewage pipe network system, and mixed with urban sewage to get subsequent processing. The model consists of pretreatment, anaerobic treatment, aerobic treatment, sludge treatment, biogas purification, storage and use of composition. This model is applicable to the economically developed areas with less planting around dairy field.

(4) Centralized Treatment. In intensive and large-scale breeding communities or regions, the surrounding farms manure or sewage is collected to get centralized treatment. Due to sharing of one set of equipment, input and cost is decreased while cost for transportation and storage facilities increases. And, it’s necessary to prevent regional health and safety risks.

5.3.5 Manure Treatment：Case Study

(1)Aerobic Compost

Aerobic composting technology is an effective solution to treat animal waste. In this paper, an excellent large-scale project in domestic cattle farming is exampled. Dongying Earth Biological Technology Co. Ltd. It’s a project which ensures an annual output of 20,000 tons of organic fertilizer, bio-organic fertilizer and organic-inorganic compound fertilizer production. Bio-organic fertilizer production process mainly concern as follows: Pretreatment of raw materials, The First Fermentation, Aging and Fertilizer. Aerobic fermentation process is in raw organic manure fermentation, then mixing of organic fertilizer and inorganic to get powder and granular of compound fertilizer. Ingredients are charged automatically by computer, and granulation is from pressure grain and grinding process by flat molding machine.

(2) Anaerobic Digestion

Beijing Sino Farm Co., Ltd. is located in southwest of Beijing and holds 4400 heads cow, of which are 2000 heads lactating cows with casual feeding pattern. Manure and Sewage treatment process is Manure Collection by scrapper and transportation by truck. After solid-liquid fraction separation, solid part is transported to manure fermentation processing center. Although there is lack of safety inspection, organic fertilizer is very popular among farmers in vicinity area. The liquid manure is used for biogas production, while biogas is not stable because of un-purity. While emission of biogas is unwanted, part of biogas is directly discharged into air. And biogas slurry partly is applied to arable farm or agriculture land, the rest almost unsaleable due to the difficulty of transportation.

5.4 Conclusion

Manure management plays a key role in the sustainable development of the dairy industry in China. Results obtained in this project indicated that the pollution control, energy recovery, and nutrient utilization in dairy manure should be improved for China dairy farms. Further research and extension should be aimed at increasing the manure nutrient efficiency. The first work should be the measurement of the gas emission in dairy manure and then to determine which step to control the pollution for manure treatment process. In addition, anaerobic digestion was widely used to recovery energy from diary manure and the use the digestate as a organic liquid fertilizer, the suitable biogas technology need further research for modern farms. Fortunately, both the gas emission measurement and the anaerobic digestion technology were supported in SDDDC Project-2016.

CHAPTER 6 2015-R3 Microbial Detoxification of DON

6.1 About Principle Investigator

Professor Hong Jian YANG

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Short Curriculum Vitae

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Field of expertise

His current research interest includes feed evaluation, anaerobic methanogensis inhibition and microbial degradation of forage cell wall in the ruminant animals with aims to improve feed conversation with less environmental pollution.

Scientific publications are available at:

http://www.researcherid.com/rid/A-6816-2010

6.2 Objectives of the study:

Fusarium is considered to be the most important toxigenic fungi, since they produce the most prevalent mycotoxins, including secondary metabolites of deoxynivalenol (DON) and zearalenone (Seeling et al., 2006). Eriksen & Pettersson (2004) noted that dietary intake of DON could cause vomiting and animal intestinal dysfunction (e.g., diarrhea, vomiting), oral mucosa and dermal damage, decreased immunity and so on. Rodrigues & Naehrer (2012) in a three-year survey on the worldwide occurrence of mycotoxins reported that a detection rate of DON was 59%, and the average of its content was 1104 μg/kg in the feedstuffs and feed sampled from the USA, Europe and Asia. Some previous studies reported that ruminants could be relatively resistant to toxic effects of DON, since the potential of ruminal microbes might degrade DON to the less toxic metabolite of de-epoxy DON (Curtui et al., 2005; Seeling et al., 2006). The objective of this study was to determine the effect of DON at different level on in vitro fermentation by assessing rumen fermentation with two forage to concentrate ratios.

6.3 Main report of the research:

6.3.1 Materials and Methods

The experimental include two substrate treatment (HF, Chinese wildrye grass hay: concentrate = 4 : 1; LF, Chinese wildrye grass hay: concentrate = 1 : 4). Freshly prepared buffer (pH 6.85, 50 mL) and 25 mL strained rumen fluid (from three rumen-cannulated lactating Holstein cow) were dispensed into a 150-mL bottle containing 500 mg rations. The working solution of DON was added to each bottles,resulting in 0, 0.5, 1, 1.5, 2 μg DON per mL of the culture fluids and the level of 1 μg/mL was equivalent with the limits standards of the state. After the in vitro fermentation .Collected the filtrate and washed the nylon bags together with the contents to clear used distilled water. Then dried at 65 °C less than 48 h to a constant weight.

6.3.2 Gas Production and Curve Fitting

The cumulative gas production values (GP, mL/g dry matter), exported from the automated gas production recording system, were fitted with time (t) to the exponential model (France, J. et al.)[10] as Equation (1):

$$GPt = A \times [1 - e^{-c \times (time - lag)}] \qquad (1)$$

where A is the asymptotic gas production; c is the gas production rate; and t is the gas recording time. The parameters A, c and lag were estimated by an iterative least squares procedure using the NLIN procedure of the Statistical Software Package for Windows (version 9.02, 1999; SAS Institute Inc., Cary, NC, USA). The average gas production rate (AGPR, mL/h) [11] was calculated to obtain the rate between the start of the incubation and the time at which the cumulative gas production was half of its asymptotic value with Equation (2):

$$AGPR = \frac{A \times c}{\log(2) + c \times lag} \quad (2)$$

Where AGPR is the gas production rate of 1/2 maximum gas production (mL/h). And according to (2005) the methods of Grings etc. to calculate the time of maximum gas production of 1/2 (T1 / 2, h) with equation (3)

$$T_{1/2} = \log(\frac{2}{c}) + lag \quad (3)$$

6.3.3 Results

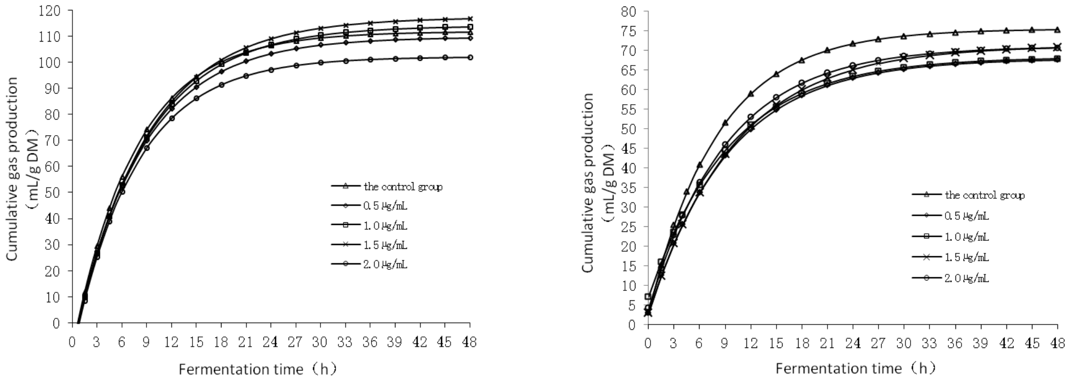
6.3.3.1 Effect of DON in IVDMD and gas production kinetics

In the present study, IVDMD and gas production for 48 h was greater in LF than HF(P < 0.01). Neither IVDMD nor kinetic gas production was affected by the DON addition(P > 0.05).With the increasing of DON dose, the gas production rate (c) showed a significant secondary correlation(P < 0.05), decreased first and then increased. When the dose of DON was 1.5 μg/mL, it was the lowest.

Table 6-1 Effect of DON addition on in vitro dry matter disappearance and gas production of diets with low (LF) and high (HF) forage contents

Items	Diet	DON Level (μg/mL)					SEM	*P* value			
		0	0.5	1.0	1.5	2.0		Diet	I	L	Q
IVDMD	HF	0.538	0.551	0.539	0.536	0.538	0.006	<0.001	0.798	0.440	0.681
	LF	0.800	0.797	0.803	0.795	0.796					
GP_{48}	HF	77.1	69.3	69.2	72.4	72.5	3.485	<0.001	0.433	0.335	0.848
	LF	112.8	109.1	113.2	117.8	102.2					
A	HF	75.4	67.9	68.2	71.3	71.0	3.266	<0.001	0.353	0.324	0.651
	LF	111.9	109.7	114.1	117.2	102.1					
c	HF	0.123	0.107	0.105	0.100	0.109	0.006	0.007	0.898	0.244	0.031
	LF	0.130	0.122	0.118	0.114	0.131					
$T_{1/2}$	HF	2.52[b]	2.61[ab]	2.80[a]	2.66[ab]	2.57[ab]	0.113	0.026	0.894	0.923	0.242
	LF	2.84	2.90	2.86	2.81	2.78					
AGPR	HF	13.94[a]	11.08[b]	10.55[b]	10.91[b]	11.76[ab]	1.575	<0.001	0.964	0.457	0.329
	LF	20.97	19.62	20.20	19.80	19.93					

I: Interaction effect between diet and DON addition, L: Linear effect of DON addition, Q: Quadratic effect of DON addition, IVDMD: In vitro dry matter disappearance, GP_{48}: cumulative gas production at 48 h (ml/g DM), A: the asymptotic gas production (ml/g DM), c: the fractional rate for the gas production of A (/h), Half-time: the time at which half of A is reached (h), AGPR: the gas production rate at which half of A is reached (ml/h).



(a) (b)

Figure 6-1 Cumulative gas production profiles of in vitro fermentation of diets with low(a) and high(b) forage contents in response to different of deoxynivalenol dosage in culture fluids

6.3.3.2 Effect of DON on ammonia N, VFA concentrations and VFA pattern

Table 6-2 Effects of DON supplemental level on in vitro fermentation characteristics diets with low (LF) and high (HF) forage contents

Items	Diet	DON Level (μg/mL)					SEM	*P* value			
		0	0.5	1.0	1.5	2.0		Diet	I	L	Q
pH	HF	6.88	6.84	6.87	6.87	6.86	0.014	<0.001	0.762	0.176	0.283
	LF	6.83[a]	6.78[ab]	6.78[ab]	6.79[ab]	6.78[b]					
NH_3-N	HF	26.72	26.90	28.20	26.43	26.41	0.662	<0.001	0.974	0.773	0.216
	LF	32.62	32.03	33.68	32.46	32.46					
MCP	HF	0.73[b]	0.81[a]	0.68[b]	0.54[c]	0.67[b]	0.088	0.158	<0.001	0.107	0.013
	LF	0.69[a]	0.69[a]	0.69[a]	0.67[a]	0.81[b]					
tVFA	HF	126.3	122.3	112.0	104.0	100.3	4.737	0.020	0.841	0.002	0.738
	LF	142.9[a]	138.4[ab]	136.3[ab]	113.2[b]	111.4[b]					
		VFA pattern(molar,%)									
Acetate	HF	53.7	54.6	54.4	55.3	54.6	0.727	0.066	0.450	0.281	0.176
	LF	51.8	54.6	54.5	52.4	53.8					
Propionate	HF	28.5	28.1	28.0	27.8	27.8	0.607	0.289	0.502	0.166	0.148
	LF	29.2[a]	26.8[ab]	26.5[b]	27.7[ab]	27.3[ab]					
Butyrate	HF	12.9	12.3	12.6	12.1	12.6	0.200	<0.001	0.014	0.556	0.685
	LF	13.5	14.3	13.8	14.2	13.7					
Valerate	HF	1.77	1.64	1.74	1.61	1.71	0.048	<0.001	0.235	0.468	0.652
	LF	1.95	1.94	1.90	2.01	1.89					
Isovalerate	HF	3.08	2.91	2.88	2.89	2.75	0.084	<0.001	0.451	0.067	0.423
	LF	3.35[ab]	3.18[ab]	3.31[ab]	3.52[a]	2.99[b]					
NGR	HF	2.57	2.71	2.61	2.76	2.77	0.061	0.163	0.593	0.049	0.15
	LF	2.59	2.82	2.85	2.79	2.75					
FE	HF	0.789	0.781	0.781	0.78	0.780	0.003	0.722	0.901	0.113	0.11
	LF	0.789	0.778	0.777	0.783	0.780					
CH_4e	HF	19.95[c]	19.68[c]	20.78[c]	27.83[b]	35.96[a]	0.683	0.001	<0.001	<0.001	0.002
	LF	18.90[d]	27.62[b]	24.42[c]	31.63[a]	32.67[a]					

NH_3-N: ammonia nitrogen (mg/dL), MCP: microbial crude protein (mg/mL), tVFA: total volatile fatty acids (mM), NGR: ratio of non-glucogenic to glucogenic acids, FE: fermentation efficiency, CH_4e: methane production evaluated. I: Interaction effect between diet and DON addition, L: Linear effect of DON addition, Q: Quadratic effect of DON addition, FE: fermentation efficiency, CH_4e: methane production evaluated, NGR: ratio of non-glucogenic to glucogenic acids.

In the present study, ammonia-N concentration was greater in LF than HF($P<0.01$).Total VFA production in LF was greater than HF($P=0.003$) and the pH was lower in LF than HF($P<0.01$).The molar percentage of acetate was greater in HF than LF though kinetics gas production was not statistical affected ($P=0.066$),but those percentages of butyrate, valerate and isovalerate were lower in HF than LF($P<0.01$),and other VFAs were not affected. The methane production evaluated (CH_4e) of HF group was lower than LF group ($P<0.01$), but the ratio of non-glucogenic (e.g., acetate, butyrate) to glucogenic (e.g. butyrate) VFAs (NGR) and fermentation efficiency (FE) were not affected significantly.

The microbial protein concentration and molar percentage of butyrate were decreased in HF group,but increased in LF group with the increase of DON addition level. Total VFA production has an interaction effect between ration and DON dosage that total VFA production tended to linearly decline with the DON addition regardless of HF or LF. Molar percentage of isovalerate has an tendency to decreased by the DON addition ($P=0.067$), NGR and CH_4e was linearly increased. Regardless of forage to concentrate ratio in the rations, the total VFA production linearly decline with DON addition, especially DON level of ≥1 μg/mL, but other fermentation characteristics were not affected by DON addition.

6.3.3.3 Degradability of DON by rumen microorganisms.

DON disappearance rate decreased linearly with increasing DON dosage ($P<0.01$), and the disappearance rate in HF group was significantly higher than LF group at 3 h ($P<0.01$). DON was mainly degraded in the first 6 h, and the average disappearance rate at 6, 12, 24, 48 h was 30%, 33%, 38%, 41% , respectively, and HF group was 5% higher than the LF group.

Table 6-3 Microbial disappearance (%) of DON in rumen fermentation of diets with low (LF) and high (HF) forage contents

Items	Diet	DON Level (μg/mL)				SEM	*P* value			
		0.5	1.0	1.5	2.0		Diet	I	L	Q
3 h	HF	29.75^{a}	22.45^{ab}	19.62^{b}	20.12^{b}	1.439	0.006	0.304	0.001	0.101
	LF	21.65^{a}	18.80^{ab}	17.49^{ab}	15.64^{b}					
6 h	HF	49.36^{a}	25.48^{b}	19.52^{c}	24.24^{bc}	2.055	0.595	0.722	<0.001	<0.001
	LF	49.51^{a}	28.49^{b}	23.54^{b}	21.84^{b}					
12 h	HF	52.51^{a}	37.59^{ab}	25.14^{c}	23.91^{c}	1.416	0.213	0.44	0.004	0.025
	LF	49.12^{a}	31.48^{b}	23.89^{b}	25.12^{b}					
24 h	HF	51.95^{a}	38.39^{ab}	24.32^{b}	31.61^{b}	1.596	0.101	0.545	0.001	0.003
	LF	55.45^{a}	38.98^{b}	26.68^{b}	38.61^{b}					
48 h	HF	57.24^{a}	41.82^{b}	34.82^{b}	29.58^{b}	1.492	0.425	0.043	0.002	0.014
	LF	50.16^{a}	42.5^{ab}	32.87^{b}	42.87^{ab}					

6.4 Conclusion

Except forage to concentrate effect, though no statistical effect on nutrient digestibility and kinetic gas production were observed, the remarkable decline occurred for total VFA production when the DON addition level was greater than 1 μg/mL as equalent acceptable level of 5 mg DON/kg feed. The DON addition increased the ratio of non-glucogenic (e.g., acetate, butyrate) to glucogenic (e.g. propionic acid) VFAs as well as CH_4 production, suggesting that DON exhibited detrimental effect on rumen microbial metabolism.

6.5 Appendix

6.5.1 Effect of DON in IVDMD and gas production kinetics

Technology of rumen fermentation gas produce can estimate feed digestibility in animals, measure feed digestibility, evaluate interaction between additives and feed rapidly, provide gas production kinetics data. (Makkar，2010；Menke et al.，1979；Van Der Meer et al.，1988)[17, 18, 19]. It is based on IVDMD and gas production, Carbohydrates and crude protein is the main source of gas production during substrate fermentation, impact gas fermentation characteristics of substrates in vitro culture directly. IVDMD is higher and the gas production is more, indicates that a higher degree of fermentation of feed in rumen and a higher degradable rate. The results in this experiment, when the ratio of forage to concentrate is different, IVDMD and all gas production ratio of kinetic parameters showed a significant difference, which indicated that there is a great relationship between fermentation aerodynamic characteristics and components and physical chemical properties of substrate. With the increasing of DON doses, the gas production was decreasing, though it was not significantly different in statistics. In addition, it showed a significant quadratic relationship between Gas production rate and DON dose. And the minimum appeared at 1.5 μg/mL.

Trenholm et al. (1985) stated that DON concentrations increased from 1.5 mg / kg to 6.4 mg / kg for concentration feed, the consumption of fodder just have slight and temporary reduction, and the weight gain and hay consumption was not be affected [20]. And in this experiment, after adding DON, IVDMD of HF group changed slightly among 2.5 mg/kg (0.5 mg/μL) and 10 mg/kg (2 mg/μL). This is consistent with the results of previous studies.

Seeling et al. (2006) pointed out, DON cannot be completely degraded by rumen microbial [21]. The degree of degradation affected by animal species, age, sex and feeding methods, because these factors will influence the type and quantity of the rumen microflora. The results of this experiment can explain that DON will reduce the rate of digestion and metabolism of ruminants, which is consistent with the previous studies.

All those stated that DON has a negative effect on the fermentation of feed. But with the addition of DON, IVDMD and gas production characteristics were not affected. But the reason is still unclear. For now, there is not a report about the effect of DON on gas production in vitro fermentation of dairy cows at home and abroad.

6.5.2 Effect of DON on ammonia N, VFA concentrations and VFA pattern

Carbohydrate and crude protein is the main source of gas production, and the gas production is a very important indicator, usually the higher degree of fermentation, the higher gas production [22]. The MCP concentration, total VFA production and the molar percentage of butyrate, isovalerate, valerate in LF group is greater than HF group is very significant, and that means the LF group has higher proportion of concentrate than HF group and more available ingredient fermented by rumen microbes. As to the fermentation characteristics, the difference of some indicators is significant between HF group and LF group, and some not. This may be caused by the combined effect of forage to concentrate ratio and the DON addition. The difference of HF group and LF group may be removed by the addition of DON. The effect of DON on ruminants is very difficult to evaluate, because the microbial environment of the rumen and its inherent detoxification potential is often considered a first defense mechanism to prevent the harmful substances [23]. Many researches have demonstrated that DON can be metabolized as DOM-1, a less toxic metabolite [24, 25]. When ruminal pH declines below 5.2, the transformation of DON will be inhibited completely in vitro [25]. And the pH in the present study is within the normal range, so the metabolism of DON will not be influenced by pH. Dänicke et al. (2005) reported that rumen pH and VFA fed Fusarium toxin-contaminated wheat were not influenced by contamination of the wheat, but the postprandial ammonia concentration was consistently higher[26].This is in agreement with our study. However, Jeong et al.(2010) demonstrated that DON negatively impacts certain aspects of rumen fermentative capacity, such as total gas and VFA production. The result of present study in agreement with feeding trial [8], but inconsistent with in vitro trial [3], this difference may be caused by the different addition level and trial condition.

6.5.3 Degradability of DON by rumen microorganisms.

Many researchers have demonstrated that DON can be metabolized as DOM-1 by rumen microorganisms [23,25,27]. In the meantime, mycotoxin may modify the ruminal microflora and weaken detoxicating effects of rumen microorganisms [24]. In the present study, DON degradation was influenced by concentrate/forage ratio and DON dosage. Apparently, degradation tend to more efficiently in HF group than LF group, which is agreement with previous study [4], but we have a higher degradation. King et al. [23] observed that, when the concentration of DON in rumen fluid from 10 ppm to 100 ppm, the transformation rate from 89% to 37% within 48 h, which proves higher concentration, lower degradation. On the contrary, some researchers consider that higher substrate concentrations may promote the transformation of DON to DOM-1 by inducing greater microbial enzyme activity. In addition, the degradation of DON influenced by various factors, such as pH level, incubation time [25]. So, the degradation rate would be different under the different experiment conditions.

Part III

2015 SDDDC PPS Dutch projects

Chapter 7 2015-PPS1 Corn/hay – production & feeding efficiency

7.1 About Principle Investigator

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Short Curriculum Vitae

Education & work experience

PhD degree in Agricultural Science at Wageningen University

PhD thesis Development of a model for the prediction of feed intake and energy partitioning in dairy cows

MSc degree in Agricultural Science at Wageningen University

BSc degree in Agricultural Science at Rijks Hogere Landbouwschool Groningen

Appointed as researcher since 1993 at Wageningen Livestock Research

Experienced specialist in ruminant nutrition, nutrition of dairy cows and dairy young stock

Field of expertise

Animal Nutrition and Feeding - Ruminant nutrition, nutrition of dairy cows and dairy young stock

Including ration and diet formulation and feeding strategies of dairy cows and dairy young stock

Animal Production Systems – Optimizing and developing ruminant (dairy cow production systems)

Including forage production, forage utilization, silage making, grazing

Mathematics – Modelling intake and performance of dairy cows

Scientific publications are available at

https://www.vcard.wur.nl/Views/Profile/View.aspx?id=2012&ln=eng

7.2 Objectives of the study

The goal of the project of the project is to improve and optimize the feed production and feed utilization in dairy cows through

1) higher dry matter and nutrient yields by improved crop and harvest management (grass, alfalfa, corn, crop residues);

2) minimizing losses during harvest, storage, improved silage preservation and feeding

3) optimizing feed utilization by the animal through optimize diet formulation and allocation of feed maximize the conversion of vegetal biomass into milk and meat

7.3 Main report of the research

Crop maturity is important for:

1) Dry matter yield
2) Feed digestibility
3) Feed composition
4) Nutrient yield
5) Losses during ensiling and feed-out

Optimizing crop maturity at harvest

1) Monitor your crops weekly
2) Alfalfa: cut between green bud and 10% flowers
3) Grass: before appearance of the ears (flowering)
4) Corn: > 30% Dry matter in the whole crop-> 1/2 milk line

Optimizing crop maturity at harvest

1) Corn: > 30% Dry matter in the whole crop-> 1/2 milk line
2) Too early (<30% dry matter) compromise
    a) Dry matter yield
    b) Feeding value: reduced energy and starch yield
    c) Silage losses -> Effluent loss
    d) Feed intake

Too late (>38% dry matter) compromise

a) Silage compaction
b) Losses during feed-out -> heating
c) Feed intake

Harvest too early is more harmful than too late

Make a good planning of harvest and logistics

1) Cut not more than you can handle
2) Grass & Alfalfa: Use well adjusted tedders and rakes
3) Capacity of harvest machinery should match with ensiling equipment (compaction vehicles)
4) Use precision chop harvesters for alfalfa corn silage
5) Corn silage: theoretical lenght of cut 6-8 mm
6) Use a grain cracker / kernel processor clearance 1-2 mm
7) Assess chop size and kernel processing

Dry matter content at harvest

Grass & Alfalfa: Field period is most important under wet conditions maximum 72 h drying on the field

Target dry matter contents at harvest:

Grass silage	35% - 45% DM
Alfalfa silage	32% - 38% DM
Corn silage	30-38% DM*

Use an additive below the target dry matter content. Wet alfalfa silage: provide extra sugar (e.g molasses) to help the lactic acid bacteria. Grass silage: use heterofermentative lactic acid bacteria, or molasses

Reduce ensiling losses

1) Keep air out of the silage
2) Seal the bunker silo's silage clamps immediately
3) Match harvest capacity and compaction weight
    a. Compaction weight ¼ of harvest capacity (tons/h)
    b. Compaction vehicle should ride continuously
4) Use good quality plastic sheets
5) Protect plastic sheeting against damage (birds, wind)
6) Secure the plastic sheeting with sufficient weight Use sand load, car tires, straps, or sand bags

Feed intake

Feeds determined by Cow factors and Feed factors

Cow factors

a) Physiological status of the cow
b) Parity, Days in lactation, days pregnant

c) Breed, Size, BCS, Milk yield

Feed factors

a) Chemical composition
b) Dry matter content, Digestibility of Organic matter (DOM)
c) Ash, Crude protein, Starch, Sugars
d) Quantities of rumen by-pass starch and protein
e) Microbial protein and by pass protein
f) Feed intake by satiety inducing effects of feed composition

Rumen function and acidosis

The rumen is a complex organ

1) Rumen motility
    a. Mixing the feed with rumen content
    b. Fibrous feeds stimulate motility of the rumen and rumination
    c. Motility induced by stimulation of receptors in the rumen wall
2) Rumination increase saliva production
    a. Bicarbonate in saliva buffers rumen pH
3) Rumen pappilae increase surface
    a. Absorption of volatile fatty acids through rumen wall
    b. Clearance rate of VFA from rumen affect rumen pH
    c. Rapid clearance is important to avoid low rumen pH
    d. Development of papillae important-> Absorption surface
    e. Rumen papillae influenced by diet -> adaptation
4) Rumen pH
    a. Fluctuate pH decrease after a meal
    b. Large meals result in larger drops of rumen pH
    c. Rumination helps buffering rumen pH through saliva production
5) Rumen acidosis
    a. Acute rumen acidosis – “off feed syndrome” – Grain induced

        Occurs sudden, only individual cows

    b. Sub-acute rumen acidodosis SARA

        Rumen pH <5.9 for more than 4 hours

        Large proportion of cows in the herd
6) Prevention of SARA
    a. Sufficient fiber in the diet,
    b. Frequent feeding of feed >3 times a day -> small meals
    c. Avoid competition for feed

Feeding systems

1) Individual concentrate feeding
    a. Better suited for smaller farms <500 cows
    b. Investments in computers, concentrate feeders
    c. Higher feed efficiency less over and under feeding
2) TMR
    a. Group cows according milk production or stage of lactation, age
    b. Form balanced groups minimize variation in groups

Formulation of TMR rations

1) Monitoring the cows - >Cow signals
    a. Milk Production of cows,
    b. Body condition score
2) Manure
    a. Grain kernels, fiber - >cow signals
    b. Consistency/texture of manure sticky thin fluid
3) Cow behaviour – rumination behaviour, rumen fill
4) Sorting of feeds
5) Amounts of feed consumed
6) Keep records!

Energy

1) Milk production
2) Milk composition
3) Calculate the energy requirements
4) Feed intake of the group

Protein

1) Metabolisable protein requirements
2) Chinese MP requirements (NRC system)
3) Crude protein
4) Shortage may impair fiber digestion
5) Rumen microbes need N

Recommendations:

Early lactation (<120 DIM, high yielding) >18% Crude protein

Mid and late lactation (>120 DIM) >16 % Crude protein

Dry cows (drying off – 2 week before calving) >14% CP

Other dry cows (< 2week before calving) like Early lactation

Starch

Recommendations:

Early lactation (<120 DIM, high yielding) >18% Starch in the diet

Mid and late lactation (>120 DIM) <15 % Starch in the diet

Dry cows (drying off – 2 week before calving) no starch

Other dry cows (< 2week before calving) like Early lactation , so rumen microbes can adapt to the lactation diet

Particle size

Use chopped feeds

Prevents sorting by the animals

Improves mixing

Recommendations feeding TMRs

Feeding frequency

> 3 times/ day fresh feed

> 3 in between pushing the feed to the feed bunk

> 3 times feeding: smaller meals

Smaller meals less risk for SARA

Less competition at feed bunk, less fighting for feed

7.4 Conclusion

Good feeding management is a matter of low cost and high competence!

7.5 Appendix

7.5.1 Handbook Alfalfa

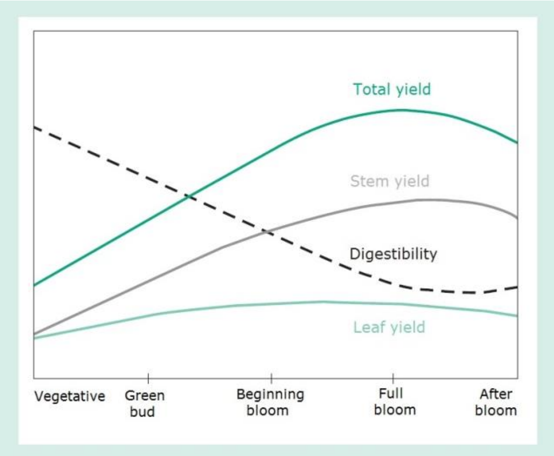
7.5.1.1 Alfalfa

Summary

Stage of maturity at cutting affects the annual dry matter yield per cut, the number of cuts and total dry matter yield. The stage of maturity at cutting has also major effects on the feeding value (Net energy, crude protein, fiber) of alfalfa hay and silage. The conditions during harvesting, as well as the type of cutting and harvest equipment and machine settings may affect the losses of leaves and thereby influencing feeding value. Furthermore, maturity at cutting affects also the persistency of the alfalfa stands.

Stage of maturity at cutting

The stage of maturity at has a major impact on the feeding value of alfalfa. The feeding value of alfalfa is strongly influenced by the leaf to stem-ratio and the fibre content of the stem fraction. The digestibility of the leaf fraction is approximately 85%, whereas the digestibility of the stem fraction is approximately 50%. Thus, a higher leaf to stem-ratio results in higher whole crop digestibility. The proportion of leaves in the total dry matter yield decreases and the proportion of stems increases with advancing maturity of the crop (Figure 7-1).



Source: Diagnostic Juide Pioneer

Figure 7-1 Effect of stage of maturity (x-axis) on the total yield, stem yield, leaf yield and digestibility

For the production of high quality alfalfa silage or alfalfa hay it is recommended to cut at an early stage of maturity when or when the first (green) flower buds are visible: the green bud stage. At the green bud stage, the organic matter digestibility (OMD%) varies between 70 and 75%. For the highest dry matter yield, alfalfa should be cut when 10% of plants is flowering. At this stage of maturity the plant has sufficient carbohydrate stores, necessary for a rapid regrowth after cutting. However, at this stage OMD% varies between 60 and 65%.

Cutting at an early stage of maturity results in a higher leaf to stem ratio and subsequently in a higher digestibility. However, cutting at an early stage of maturity results also in lower dry matter yields per cut. Whereas cutting at a late stage of maturity results in a lower leaf to stem ratio and subsequently to a lower digestibility, but with a higher total dry matter yield per cut. However, cutting at an early stage of maturity has also a disadvantage because it reduces the carbohydrate stores in the plant. Low carbohydrate stores reduce the growth rate of the regrowth, and consequently a reduced dry matter yield. A reduced growth rate also impairs the competitiveness of the alfalfa stand often resulting in a greater invasion of weeds. When the carbohydrate reserves are not sufficient restored before the winter season it may reduce winter survival of the crop. Therefore, repeated cutting at an early stage of maturity may compromise total dry matter yield per year. Farmers should find the balance between a high feed quality and a high dry matter yield.

Research in the Netherlands at Wageningen UR showed that two cuts at an early stage of maturity (green bud stage) followed by late cuts (10% flowering) resulted in the best compromise between dry matter yield and feed quality (Table 7-1).

At the end of the growing season, the crops taller than 15 cm should be cut before the winter in order to create a new spring regrowth without death stems and plant residues from the previous season.

Table 7-1 Yield of dry matter and net energy (NEL) of alfalfa haylage (wilted alfalfa silage) with 4 different cutting regimes with early and late cuts. Early cuts: cutting at green bud stage; Late cuts at 10% of the plants flowering

	Number of cuts	Dry matter yield tons/ha	Net energy MJ NEL/kg DM	NEL yield MJ NEL/ha
Only late cuts	3	11.5	5.60	64432
2 Early cuts, followed by late cuts	4	11.4	5.95	67884
3 Early cuts, followed by late cuts	4	10.7	5.98	63937
Only early cuts, followed by late cuts	5	10.3	6.11	62968

Harvest of alfalfa haylage and hay

Harvest methods and techniques are crucial in prevention of losses at the field and achieving a high quality alfalfa haylage (wilted silage) or hay. It is important to minimize te losses of leaves and avoid contamination of haylage with soil. This requires adequate machinery and machine settings and rapid wilting and drying.

Cutting and conditioning

Table 7-2 The effect of stubble height on the yield of dry matter and net energy (NEL) of alfalfa haylage (wilted alfalfa silage)

Stubble height	Dry matter yield tons/ha	Net energy MJ NEL/kg DM	NEL yield MJ NEL/ha
6 cm	10.8	6.01	64910
11 cm	10.4	6.08	63221

Alfalfa is usually cut using disc cutter bars (disc mowers) or sickle cutter bars (sickle mowers). Drum mowers are less suitable because higher losses of leaves. The knives must be sharp to avoid a ragged cut. A stubble height of at least 6 cm is recommended. Stubble height has little impact on the feeding value. The feeding value is slightly increased with higher stubble heights (Table 7-2).

To improve drying speed, it is recommended to cut alfalfa when the crop is dry (no moist from dew or rain). Drying speed can be increased by wide swaths and the use of conditioners. There are two types of conditioners to be distinguished: roll conditioners and flail conditioners. In general, roll conditioners are preferred for alfalfa because lower losses of the leaf fraction. Roll conditioners crush and break the stems of alfalfa. Adjustment of roll conditioner (roll clearance, pressure and speed) affects the condition and drying speed. Swaths dry more rapid at the surface than at the bottom. Therefore, swath inversion machines which gently lift and invert the swath can be used for more uniform drying. Sometimes the crop is spread using a hay tedder machine for uniform drying. Hay tedders should only be used in a wet (green) crop with less than 30% dry matter. Using hay tedders in a dry crop cause loss of leaves resulting in a reduced digestibility and feeding value.

To prevent losses of leaves, it is recommended to windrow alfalfa when the crop is still moist to prevent losses of leafs. Furthermore, it is important to check the setting of the windrow machinery. Losses of leafs can be reduced by a proper adjustment of the rakes, relative low ground speed and low rotation speed of the rakes.

For the production of alfalfa haylage (wilted alfalfa) silage, the time on the field between cutting and ensiling (field period) should be no longer than 2 days.

For the production of alfalfa hay requires for at least 4 days good (dry, windy) weather conditions. Alfafa hay should be baled at a dry matter content of 80%. Below 80% DM, forced air ventilation of hay in necessary to prevent moulding.

Harvesting and ensiling

Precision chop harvesters are recommended to harvest alfalfa silage. Precision chop harvesters homogenise the silage by mixing the relative dry material at the surface and relative wet material at the bottom of the windrow. A well-mixed homogenous silage is advantageous for the ensiling process. Precision chopping is also advantageous for a dense packing of the silage which reduces air penetration of the silage.

For lactic acid fermentation of the silage sufficient available sugars and anaerobic conditions are essential for a good silage preservation. Alfalfa is relatively low in sugar and relatively high in protein which are unfavourable conditions lactic acid fermentation and a rapid decrease of the pH in the silage. Adding sugar beet molasses or sugar cane molasses at a rates of 5% (of the dry matter) with dry matter contents above 35% and 10% (of the dry matter) for alfalfa silage with a dry matter content between 20 and 35%. For a good mixing of the molasses it is recommended to dose the molasses on top of the swath immediately before harvesting with a precision chop harvester.

For a good alfalfa haylage (wilted alfalfa silage) preservation the following rules should be considered.

a) Cut the crop at early maturity
    - From green bud stage to 10% flowers
b) Aim at 35 to 40% dry matter at harvest
c) Use a precision chop harvester
    - For better compaction and homogenisation
d) Use molasses as an additive to provide sufficient sugars for lactic acid bacteria
    - 5% of the dry matter yield in alfalfa with more than 35% dry matter

- 10% of the dry matter yield in alfalfa with 20 to 35% dry matter

e) Create anaerobic conditions

- Use heavy weight vehicles for a good compaction of the silage
- Seal the silage bunker within one day
- Use good quality plastic sheeting and protection sheets

Figure 7-2 Good compaction with a heavy weight vehicle

Alfalfa in dairy cow rations

Alfalfa haylage and alfalfa hay are suitable for all categories of ruminant livestock. As pointed out earlier, stage of maturity at cutting is an important factor for the nutritive value. In general, alfalfa haylage and hay is relative high in in protein, and digestible organic matter. Alfalfa is also a good source of effective fiber. Compared to corn silage, the net energy value of alfalfa haylage is lower, but the crude protein content is higher.

If good preserved, alfalfa haylage and hay is a very palatable feed allowing high intakes. For dairy cows it is important to cut the alfalfa at green bud stage. Cutting at early maturity results in higher feeding value (Table 7-3). Moreover, early cutting was also associated with higher intakes and improved performance (Table 7-4).

Table 7-3 Effect of stage of maturity in the Netherlands on chemical composition and feeding value.

	Green bud stage	10% flowers
Crude protein	210	172
Crude fiber	228	303
Ash	139	119
NH_3-Nitrogen (%of total N)	11	12
Digestibility Organic matter (%)	70.5	64.5
Rumen fermentable organic matter	458	430
Net energy for lactation NEL (MJ/kg DM)	5.5	5.0
DPI	55	43
RDP	103	76

Values in g/kg dry matter, except where indicated else. DPI = digestible protein available in the intestine, RDP = rumen degradable protein

Table 7-4 Effect of stage of maturity of alfalfa haylage on feed intake and milk performance in the Netherlands. Experiment with mid lactation dairy cows.

	Green bud stage	10% flowers
Intake alfalfa haylage kg DM/cow/day	14.3	13.2
Intake concentrate kg DM/cow/day	8.6	8.6
NEL intake MJ/cow/day	139	129
Energy corrected milk yield kg/cow/day	33.7	32.3
Milk energy output MJ/cow/day	104.4	100.2

Compared to grass hay, alfalfa haylage and hay has a higher proportion cell contents and a lower proportion cell wall. Alfalfa hay contains more pectin than grass hay. Compared to grass hay alfalfa hay contains much less hemicellulose, but the proportion of in alfalfa. In general, the total digestibility of the cell wall components of alfalfa is lower than of grass hay. However, despite this lower digestibility, the digestion rate and rumen outflow of the cell wall components is higher compared to grass silage and grass hay. Because of the higher degradation rate and outflow from the rumen, the voluntary dry matter intake of alfalfa haylage and hay is higher compared to the intake of grass silage and grass hay.

Alfalfa haylage and hay can be used as the only forage in dairy cow rations. However, alfalfa haylage and hay is high in rumen degradable protein. To improve nitrogen utilization, alfalfa haylage and hay should be combined with forages and concentrates that provide sufficient rumen fermentable organic matter. For example, good quality corn silage (30-35% DM, 25-35 % starch) is a good combination with alfalfa haylage and hay.

Alfalfa silage and alfalfa hay is good source of fiber for dairy cows receiving diets with a large proportion of concentrate.

Alfalfa in diets for rearing calves and young stock

Alfalfa haylage and hay are very suitable for rearing calves and young stock. On diets with ab libitum good quality alfalfa haylage and hay it is possible to achieve a dry matter intake of 2% of the body weight. For young stock the recommended target growth rates are 0.85 kg per day for calves between 2 to 8 months of age, 0.7 kg per day for young stock between 9 to 15 months of age, and 0.6 kg per day for rearing heifers older than 15 months.

With good quality alfalfa, rearing heifers older than 15 months can achieve a growth rate of 0.6 kg per day without supplementation of concentrate. However, it is necessary to feed them additional vitamins and trace minerals.

7.5.2 Handbook Corn Silage

7.5.2.1 Harvest

Corn silage is an import source of energy on many farms. It is important to harvest corn at the right time and according to the right procedure so that corn silage can be optimally utilized in a ration. In this chapter it is discussed which factors influence harvest time, how to determine harvest time, and the harvesting method.

(1) Maturity at harvest

The optimal harvest time of corn silage is when the whole plant obtained its maximum nutritive value, when silage losses are minimal, and when livestock can utilize the crop best. In practice, these requirements are not met at the same time or at the same percentage of dry matter. The best harvest time is a compromise between these factors.

The best compromise is achieved when the whole plant dry matter is around 36% of the fresh weight. This corresponds with a dry matter content of the cob (corn ears and husks) dry matter of 55 to 60 % and a dry matter content of the of 24 to 27%. The latter is realized when half to a quarter of the leaves remain green. Other factors that influence harvest time are the ability to harvest (stalk rot and lodging) and the accessibility of the field.

Ever early harvest due to early maturing corn varieties

① Maximum nutritive value

The maximum nutritive value of the whole plant is yielded when the whole plant dry matter is between 34 and 40%, which may vary between years. In years with favourable growing conditions the whole plant dry matter will be higher and earlier achieved in years than in years with less favourable growth conditions. The maximum nutritive value is obtained as a result of the dry matter yield and the digestibility of the crop and net energy per kg dry matter).

Digestibility

The digestibility of corn silage is mainly determined by the amount of starch, cell wall content, and the digestibility of the cell walls. The composition of corn silage changes during ripening, and as a consequence digestibility will change. The digestibility of the stover reduces but the digestibility of the cob increases. First, this is caused by conversion of carbohydrates from the stover to starch in the cob. Sugar content reduces and starch content increases. Second, it is caused by reduction in digestibility of the cell walls in the stover.

Loss of cell wall digestibility will be compensated under favourable conditions. Consequently, the whole plant digestibility will increase. Loss of cell wall digestibility cannot be compensated when conditions are unfavourable and the whole plant digestibility will decrease slightly. The annual average of digestibility remains constant during ripening. Early maturing corn varieties will yield a certain dry matter content early in the season and the chance of increasing whole plant digestibility will thus be greatest for these types of varieties.

The composition of starches changes as well during ripening. The proportion or rumen by-pass starch increases. By-pass starch is not digested in the rumen but becomes available as glucose in the intestine.

② Minimize ensiling losses

Ensiling losses are the result of effluent losses and losses during silage fermentation. To avoid effluent losses the whole crop dry matter content should be at least 32%. The preservation losses are lowest with a dry matter content between 33 and 39%. There is greater risks of heating and moulding during feed out with at a whole crop dry matter content above 36%. Good silage management will reduce the risks of heating and moulding. Important is a short theoretical length of cut (TLC, chop size) of 6 to 8 mm, dense compaction using heave weight compaction vehicles, fill the silage bunkers with layers of corn silage, air-tight sealing with good quality plastic sheeting (0.1-0.15 mm thick), protection sheets to avoid damage of the plastic.

To minimize the losses during ensiling and feed-out it is best to aim at a whole crop dry matter content between 32 and 36 %.

If it is the case that no sufficient dry matter content of the corn silage can be achieved due to extreme conditions, it is necessary to aim for a dry matter content of at least 28%. Silage losses will be limited to 10% in this way.

Optimum harvest time is when the crop has a dry matter content of 36%

③ Maximum utilization of nutritive value

Results from feeding experiments (Wageningen UR Livestock Research 2005) show that the utilization of corn silage by high yielding dairy is higher at a whole crop dry matter content of 36% compared to a whole crop dry matter content of 30%.

A higher whole crop dry matter content results in a higher concentration of starch with are larger proportion of rumen by-pass starch.

Harvesting at a later point in time corresponds with increased hardness of the grain kernels, and hence results in a decreased degradability. The kernel should therefore always be used. The grain kernels should be crushed in at least four parts in order to allow maximum utilization of the grain kernels.

④ Harvest risks

The optimal harvest time is based on the maximum nutritive value which is achieved at 36% of dry matter content. However, other factors play a role and it may be necessary to deviate from this value.

The risk of stalk rot (fusarium) increases when the dry matter content of the crop increases. Stalk rot affects the lower part of the stalk. As a result, the nutrient flow is hindered which results in plant death. The dry matter content of the crop increases and the nutritive value is influenced negatively. Sugars that are present within the plant are utilized by fusarium fungi which has a negative effect on the ensiling ability. Besides these negative effects, stalk rot increases the risk of lodging. Crops can also lodge due to lack of firmness. Lodging increases the risks of yield losses and soil in the pit.

One last factor that influences harvest time is accessibility of the field which determines whether the crop is easy to harvest or not. The crop needs to be harvest as soon as possible when there is a risk of stalk rot, lack of firmness or a bad accessibility of the field. This, despite the low yield, dry matter content or quality of the crop.

(2) Harvest management of corn silage

① **Determining of harvest time**

The maximum nutritive value is reached around a whole crop dry matter content of 36% in situations where the risk of heating of the silage is low. In situations with a higher risks of heating a whole crop dry matter content of 32% is recommend. Dry matter contents below 32% dry matter may result in large effluent losses.

Table 7-5 Recommended whole crop dry matter content at different situations

Silage conditions	Recommended whole crop dry matter content
Low risk on silage heating	36%
High feed out rate > 0.3 m/day	
Undisturbed silage face (block or rotary cutter, shavers)	
Low ambient temperature	
Dense silage packing: (>250 kg DM/m^3)	
High risk on heating	32%
Low feed out rate > 0.15 -0.3 m/day	
Disturbed silage face (grab bucket)	
High ambient temperature	
Moderate dense silage packing (200-250 kg DM/m^3)	
High risk on harvest losses	28%
Drought damaged crop	
Frost damaged crop	
Stem rot,	
Lodging of the crop	

Dehydrated corn silage often has a lower dry matter content

② **Estimation of dry matter content in corn silage**

To choose the right harvest time it is important that the dry matter content is estimated well.

The dry matter content of the whole plant is determined by the proportion opf grain , the dry matter content of the stover, and the dry matter content of the cob.

The proportion of grain

The proportion of grain as proportion of the total dry matter yield is influenced by the growing conditions (weather, type of soil, and plant density) and by the crop conditions (leafiness of the the crop and and size of the cob). In table 7-6 below it is presented how you can translate conditions to cob share.

Table 7-6 Estimation of proportion of grain

Growth and crop conditions	Cob share based on dry matter content
Bad growth conditions, high plant density. Massive crop with small cob.	40% or lower
Normal growth conditions, normal plant density. Massive crop with big cob or less massive crop with normal cob.	50%
Good growth conditions, low plant density. Less massive crop with big cob.	60%

Dry matter content of the stover

The discolouring of the leaves and the juice flow in the stem determine the dry matter content. Table 7-7 presents the relationship of the state of the stover and the dry matter content.

Table 7-7 Estimation dry matter content of stem and leave

State of stover	Dry matter content stover
Whole plant is green and fluid runs out of the stem	18%
Plant is ¾ green and stems are moist	21%
Plant is 50% green and stem is almost completely dry	24%
Plant is ¼ green and stem is completely dry	27%
Plant has no green leaves (it seems dead) [1)]	30%

[1)] If the plant is dead for some time longer it dehydrates up to 33-36% of dry matter content

Dry matter content of the cob

The dry matter content of the cob can be estimated based on the milk line of the grain kernels. The milk line is the line between the firm starch and the milk part (see figure 7-3). The milk line can be judged based on a grain kernels that arises from the middle of the cob and was cut lengthwise. Table 10.4 presents different stages of ripening and the corresponding dry matter contents of the cob.

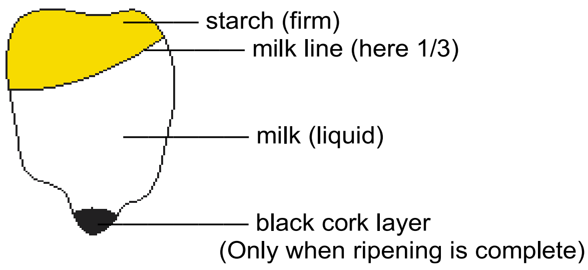
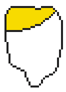
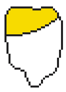
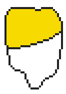
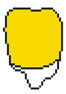
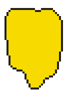
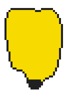


Figure 7-3 Milk line in the grain kernels

Table 7-8 Ripening stages of the corn cobs

Stage	**Milk line in the grain kernels**	**Characteristic**	**Dry matter content of the cob**
Milk		Grain kernel is white-yellow, lots of tension in the grain kernels, content looks like milk.	35%
soft dough		Grain kernel is yellow, content feels dough like, it squirts when squeezed.	40%
soft dough to hard dough		Grain kernel is dark yellow, half is moist (spindle), and other half is firm.	45%
Dough ripe		Dark yellow, moist in the spindle, other content is firm.	50%
Dent dough		Darker yellow grain kernels, content is firm, hard to press with a nail, no fluids, upper side is like cornea, and starts to dent.	55%
mature		Firm grain kernels, cannot be dented, glassy parts are as firm as cornea. Black layer of cork exists on the bottom.	60%

Combine and determine the whole plant dry matter content

Table 7-9 below shows the whole plant dry matter content based on the conditions of the proportion of grain, dry matter content of the stover, and dry matter content of the cob.

Table 7-9 Estimation of whole plant dry matter content (%)

Estimated cob share based on dry matter content (%)	40					50					60				
Dry matter content stover (%)	18	21	24	27	30	18	21	24	27	30	18	21	24	27	30
Dry matter content cob (%)															
35	22	25	27	30	32	24	26	28	30	32	25	28	30	31	33
40	23	26	29	31	33	25	28	30	32	34	27	29	32	34	35
45	24	27	30	32	35	26	29	31	34	36	28	31	33	36	38
50	24	27	30	33	36	26	30	32	35	38	29	32	35	37	39
55	25	28	31	34	37	27	30	33	36	39	30	33	36	39	41
60	25	28	32	35	38	28	31	34	37	40	31	34	38	40	43
65 1)	25	29	32	35	38	28	32	35	38	41	32	35	39	42	44

1) After the maturity stage (60% dry matter content) has been achieved, the dry matter content can continue to elevate through dehydration. Rumen by-pass starch level will increase as well.

(3) Harvest methods

Corn silage is usually harvested with self-propelled precision chop harvesters with a corn row-header or a row-independent corn header. The advantage of row-independed headers is greater flexibility and harvest.

① Stubble height

The optimal stubble height varies between 10-15 cm and this is depending on the flatness of the plot. A shorter stubble height is not desirable because of the greater risk on contamination with soil. This lowers the nutritive value and it will damage the knives of the chop harvester.

Stubbles and stems have higher moisture content than the cob and are also less digestible. This makes it possible to influence the yield and the quality with the stubble height. With each additional 10 cm stubble heigth, the concentration of Net Energy for lactation (NEL) will increase with 0.6%. On the other hand, the dry matter yield decreases by approximately 2.5%. The overall nutritional yield decreases by approximately 2% per 10 cm stubble height. In general, increasing the stubble height is thus a fairly expensive method to increase the nutritive value.

② Chop size, theoretical length of cut

The optimal theoretical length of cut is between 6-8 mm. A larger theoretical length of cut does not contribute to a better supply effective fiber or dietary physical structure for the cow and it will influence intake negatively. A large chop size results also in more selection at the feed bunk and more refusals (stalks, leaves) and feeding losses. Moreover, a larger chop size makes it more difficult to compact the silage pit resulting in a greater air penetration during feed out which may result in heating of the clamp and infection with aerobic organisms (fungi). Research by Wageningen UR Livestock Research has shown that a theoretical length of cut of 6 mm results in on average a 5 to 10% higher density (kg DM/m^3) of the silage clamp when compared with a theoretical length of cut of 15mm.

Worn out of knives and poor adjustment of the knives blades give an irregular chop length. It is therefore best to check the chop size and chopping quality several times during the harvest. The length can be checked by measuring the length of a number of right-angled chopped stems. A poor chopping quality results in long ragged parts of dry stem and leaves.

Judge the theoretical length of cut during shredding

③ Grain processing

All grains should be damaged in such way that the pieces are no larger than a quarter of the grain in order to be utilized well by cows (see also the chapter Nutrition). To crush the grains, there are several options such processor rollers (cracker rollers), ribbed based panel beneath the reel or by placing rasp bars on the blades. Most of the self-propelled precision chop harvesters have a roller. It is mounted behind the chopper unit and consists of two counter-rotating knurled crushing rollers. The grains are crushed in between the processor rollers that turn around with different speeds. The structure of the other parts of plants is little affected by the crushing rollers. The distance between the two rollers is adjustable to control the intensity of crushing. To crush well, the grain kernels crusher is set at a minimum distance of 1 mm. Using a grain kernels crusher affects the capacity of the precision chop harvester. Since a grain kernels crusher uses around 7.5 kW per row extra, the total capacity will drop with a constant drive power.

7.5.2.2 Storage

The focus of this chapter is on the silaging process and silage losses. Heating, moulding, and some contaminations will be discussed as well.

(1) Ensiling process

Ensiling requires anaerobic conditions for a lactic acid fermentation. Therefore, corn is sealed airtight using good quality plastic sheeting. A rapid development of lactic acid bacteria occurs during the first stage of silage fermentation. A rapid drop of the pH level silage reduces the growth of undesired clostridial bacteria. In corn silage, the of a stable silage is between 4.0 and 4.2. When the formation of lactic acid does not start up well, harmful bacteria can grow and they will result in a poor preservation of the silage that leads to substantial silage losses. Measures should be taken that to promote lactic acid bacteria and suppress the clostridial.

① Ensiling corn silage

Corn silage will well preserve by:

- Sufficient sugar and lactic acid bacteria. Sugars become available for lactic acid bacteria when shredding. This results in a drop of pH from 4.0 to 4.2;
- Low protein and mineral levels. Proteins slow down acidification (buffer effect). Products with lots of protein like young grass are therefore difficult to conserve.
- Relatively low temperatures in autumn that cause butyric acid bacteria to be less active.
- Well-preserved corn silage contains little butyric acid and the NH_3 fraction is low. The NH_3 fraction is therefore not determined when analysing corn silage.

Corn silage is well conservable

With a good silage fermentation, there is a sufficient amount of lactic acid produced within two weeks after ensiling to create a stable silage. The amount of lactic acid is among others dependent on the dry matter content, but it is usually around the 2% (in the fresh product).

It is important to seal the silage clamps within one after harvest. Otherwise, the temperature in the pit will rise as a result of air penetration. These aerobic conditions result in more acetic acid and less lactic acid which results in a less palatable feed and reduced intakes.

It is preferred to keep silage closed for at least 4 weeks after ensiling.

② Gas formation

Heavy gas formation sometimes occurs after sealing the corn silage. It may be necessary to tap when the plastic sheet becomes too bulb. This is usually caused by corn silage that is harvested too early (too wet, below 28% dry matter) because it contains relatively a lot of green plant parts and has relatively low dry matter content. In addition, gas formation is triggered by heavy fertilization with nitrogen and heating. With less well preserved silage, extra carbon dioxide and hydrogen will develop, while nitrate (from the green plant parts) will be broken down into nitrate and other nitrogen compounds. This mixture of gas is yellow/brown and very toxic. With inhalation or skin contact it can damage the lungs and skin (burning).

If a strong gas development occurs in a silage clamp, then it is necessary to open the plastic sealing on both sides to let the gas escape. Shortly after removing gas, it is necessary to close the pit air-tight. Sometimes it is necessary to repeat everything.

Silage pits with heavy gassing are no hazard to feeding livestock. The quality is also not or little affected. Side effects are discolouring to orange or brown. Gas formation can be prevented by normal fertilization of corn silage, harvesting at the right time, and careful silage making.

③ Ensiling losses

Silage losses in the clamp occur because of respiration of corn at the start of the conservation process and through conversion of carbohydrates and protein in organic acids and ammonia. In addition, wet corn silage (less than 32% dry matter content) can cause effluent losses. With a sufficient dry matter content of corn silage losses can occur because of limitations in conversions. There is a strong relation between the whole crop dry matter content at ensiling and ensiling losses

(figure 7-10). Research from 2003 and 2004 from Wageningen UR showed no differences between "stay green" corn hybrids and "dry down" corn hybrids (figure 7-11). At the same whole crop dry matter content, "stay green" corn hybrids have a higher dry matter content of the grain and a lower dry matter content in the stem and leave fraction compared to "dry down" corn hybrids. In short: stay green hybrid have more a mature grain, with a larger proportion of green leaves, whereas dry down hybrids have a less mature grain and higher dry matter content in the leaf and stem fraction.

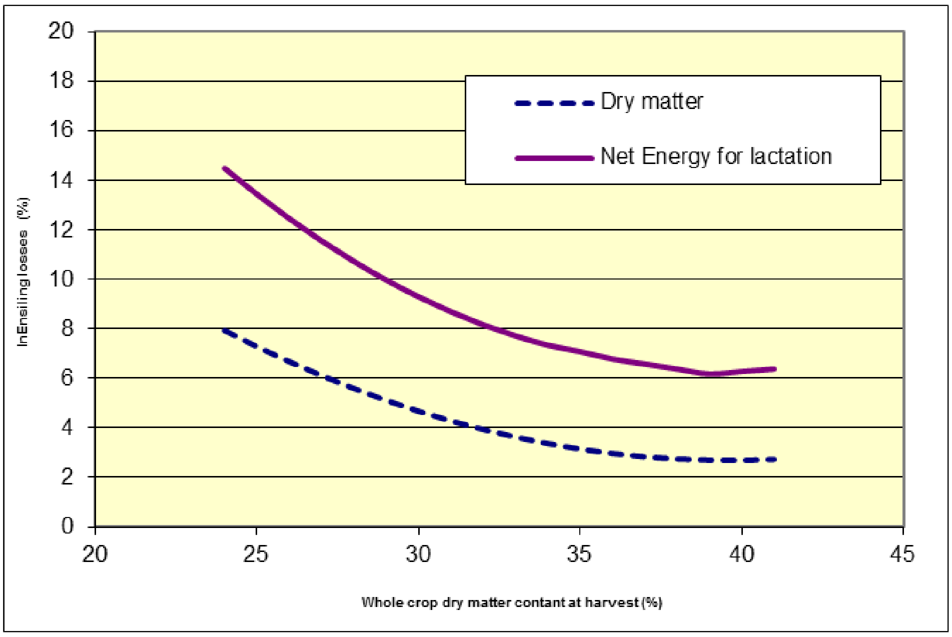


Figure 7-10 Relationship between silage losses and dry matter content at ensiling

Ensiling losses occur as a result of the ensiling process as result of the conversion of carbohydrates in lactic acid. However, these losses are very limited with a good ensiling and preservation practice.

If this is not the case, losses could rise significantly through heating, moulding, and putrefaction.

A distinction can be made between losses on dry matter content and losses on nutritive value net energy. Net energy losses (Net energy for lactation) are always higher compared to the dry matter content losses, especially in cases of humid corn. This is because the best digestible substances will be lost with the effluent during fermentation.

From research on ensiling was shown that the effluent losses are different between stay green corn hybrid and dry down corn hybrids (figure 7-11).

The threshold whole crop dry matter content to prevent effluent losses was 31% in dry down hybrids and 32.5 % in stay green hybrids. Also, more silage effluent losses occurred with stay green hybrids when the corn was ensiled at a low dry matter content. At 28% dry matter content, the amount of silage effluent was 14 and 25 litres per tonne for dry down hybrids and stay green hybrids, respectively.

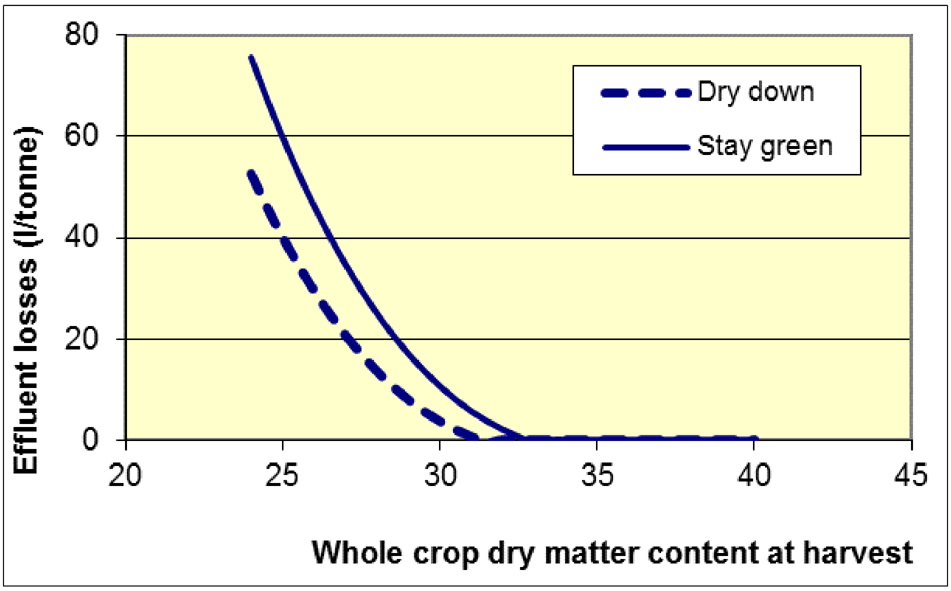


Figure 7-11 Effect of whole crop dry matter content at harvest on silage effluent losses

(2) Storage

① Dimensions of the silage bunkers

The dimensions silage clamps and bunker silos depend on minimum the feed out rate to prevent or minimize heating and moulding. To prevent heating and moulding feed out rate of 0.3 m per week is required. The preferred dimensions of the bunker silos can be calculated from feed demand per day (kg dry matter per day) and the density of silage (kg dry matter per m^3)

② Filling silage clamps and bunker silos

A number of aspects are important for easy and airtight sealing of silage clamps and bunker silos and to well and make use of the available space to get a well conserved product:

- With bunker silos it is desired to place plastic sheets alongside the walls (figure 7-12) to get a good enclosure of the upper corners.

- The silage clamps and bunkers be build up from thin layers of corn silage will result in the best compaction. Heavy wheel loaders or a heavy tractors needs to drive continuously to compact the silage.
- Fill the silage clamp or bunker in a short period (maximum 1 day) and take care of immediately airtight sealing of the silage.
- The sides of clamp need to be sloping, 60 degrees for clamps without a sand load, 45 degrees sloping for clamps with a sand load.
- In bunker silos it is important that the silage will be slightly higher on the sides compared to the middle, hence it needs to be stored in a hollow shape (figure 7-10). The sides will be more firmly compacted and the risks of damaging the walls and sheeting by the compacting vehicle are smaller.
- Silos need to be filled well and evenly until just above the walls to be able to make a good airtight and watertight enclosure.
- Clamps and silos need to have a smooth surface. In this way it is possible to stretch the plastic tightly and to promote the run off of rain water from the surface of the clamp.
- Ramps need be removed as much as possible. This saves space and plastic.

Silos are preferred for storing corn silage

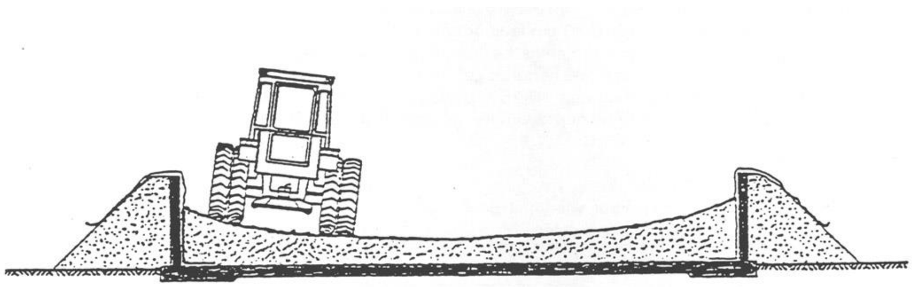


Figure 7-12 Fill the silo hollow shaped

(3) Covering and sealing of silage clamps and bunker silos

① Silage clamps and bunker silos with a sand or soil load

Using a sand load or soil load on top of the silage clamp or bunker has some advantages. First, sand load reduces air penetration en reduces the risks of heating during feed out. A sand load protects the silage against damage by birds and storm and wind. The soil on top on top of the silage should be fine and free from sharp stones and heavy clods which damage the plastic sheeting.

When using a soil load, corn silage can best be covered with 0.15 mm thick polyethylene (PE) sheeting. The layer of soil can be about 10-15 cm.

② Silage clamps and bunker silos without a sand or soil load

Sometimes it is not possible to cover a silage clamp or bunker silo with a sand or soil load. For example very high and wide bunker silos. In this situations it is necessary to put two layers of 0.15 mm thick PE sheeting on top of silage (figure 7-13). Both sheets need to be fixated with sand or sand bags on the sides.

To protect the silage against dogs, cats, birds, hail, storm and wind, it is possible to add another protection sail on top of the PE foils. It is important that the foils remain tight on top of the silage and that it is checked whether there are damages or not. An option is to use sand bags or plastic band (with sand bags or straps attached to the silo walls) to reduce the impact of wind.

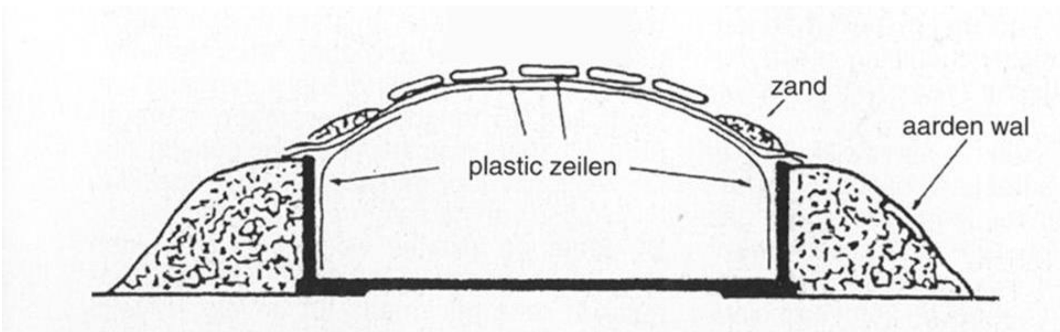


Figure 7-13 Covering a silo with plastic only

(4) Density (m^3 weight)

The density (expressed in kg dry matter content per m^3) can vary in the corn silage. This is dependent on the stack height, soil or sand load, dry matter content, theoretical length of cut, and degree of pressing. Table 7-10 shows the m^3 weights of corn silage for various situations. The density is given as an average of the whole clamp. Within the silage clamp the density may vary. In the middle on the bottom, density will be higher compared to the top and sides.

Table 7-10 Density of corn silage (kg per dry matter) per m^3 of corn silage clamps and bunkers covered with a sand load.

Stack height:	< 1,30 m		1,30 – 1,80 m		> 1,80 m	
Storage in:	clamp	bunker	clamp	bunker	clamp	Bunker
< 25% dry matter	210	220	220	235	235	245
25-30% dry matter	220	235	235	245	245	260
30-35% dry matter [2]	235	245	245	260	260	270

[1] Storage without soil coverage results in about a 5% lower density
[2] Above the 35% dry matter content, density decreases, especially when corn is stored without soil coverage

(5) Heating and moulding

Heating and moulding easily develop in corn silage. Heating and moulding is caused by penetration of air in the corn silage during conservation and feed out. Various bacteria and moulds will become active under aerobic conditions and start to grow. This results in loss of nutrients and heat production. The losses increase when heating endures or when temperature increases. Losses can increase up to 2-3% of net energy for lactation per day. Another side effect is that the product will be less palatable resulting in a reduced intake.

Prevention of heating and moulding during feed-out

- Prevent air penetration during feed-out. For silage clamps and bunker silos without a sand load, use sand bag to prevent penetration or air between the top of the clamp and the plastic sheeting
- During feed out is necessary to maintain a smooth and undisturbed silage face.
- Use heat inhibitors (propionic acis) or special mixtures with heterofermentive lactic acid bacteria. These compounds inhibit the activity of micro-organisms. This riks on heating can be diminished by adding these mixtures on top of the silage clamps before closure. However, adding propionic acid and heterofermentive lactic acid bacteria with special equipment on the chop harvesters is more effective.

(6) Moulds

Usually, moulding starts at the outside of the pit because of air flow. Sometimes there are moulds with striking colours in the middle of a well-conserved pit. These are the moulds Penicillium roqueforti, Monascus ruber, and Chrysonilia sitophila.

① Penicillium roqueforti

The Penicillium roqueforti shapes blue-green bulbs that have a diameter of 10-20 cm. These mould bulbs usually exist in the upper part (low density) of the pit, but not in the outer layer from 0-15 cm because it is too cold. This mould can grow almost without oxygen and it can produce toxins. In practice, these toxins are rare. Not everything is known about the growth conditions of this mould. It does appear that this mild usually exists in pits that have a low feed out rate. Moulding results in a less tasteful product with lower nutritive value. Therefore, it is advised to take the blue-green mild bulbs out of the pit and to not feed them. A well compacted, airtight pit and a sufficient feed out rate can diminish or even prevent the growth of such moulds.

② Monascus ruber

The Monascus ruber shapes red-purple bulbs in the corn silage. This mould grows under the same conditions as the blue-green mould. The Monascus produces almost no toxins and is not harmful. Still we advise to take out the mould bulbs, but first make sure that the corn silage is conserved well and that the feeding speed is sufficient.

Chrysonilia sitophila

The Chrysonilia sitophila is an orange mould that usually exists in the face of the clamps of heating corn silage. The mould grows with higher temperatures (25-30 °C) and can grow very fast in a couple of days only. This explosive growth leads to extra heating and a quick decline in quality (putrefaction). This mould is not toxic.

Some moulds have striking colours, like the Monascus ruber

(7) Mycotoxins

Mycotoxins are produced by moulds. A distinction is made between field moulds and storage moulds. The presence of moulds is dependent on the conditions. Field moulds are mainly affected by the weather (humidity and temperature), soil functioning, fertilization, and crop rotation. Storage moulds are mainly affected by temperature, humidity, time, and conservation. Hundreds of mycotoxins are known. From the mycotoxins that are relevant to dairy cattle, deoxynivalenol (DON), zearalenon (ZEA), and roquefortin C occur most often. DON exists mainly in grains and corn. ZEA exists mainly in corn, grasses, and a variety of feed ingredients. Both mycotoxins are produced by fusarium moulds during cultivation of the crop (field moulds) and they remain stable in the silage. Corn silage is commonly part of the ration of dairy cows and is together with grass and corn an important source of DON and ZEA Roquefortine C is produced by Penicillium roqueforti during the storage time (storage mould). The transmission of these mycotoxins from feed to milk is low (0.03% or lower).

Little is known about the metabolism and toxicity of mycotoxins in dairy cattle. DON is to a large extent degraded in the rumen. Hence, no clinical effects on the health of dairy cows or negative effects on the feed intake and milk production are expected.. ZEA is not or barely degraded in the rumen. When there is a high amount of ZEA in the feed it is not unlikely that it will have a negative effect on fertility. There is insufficient knowledge on the effect of roquefortin C on dairy cows. Table 7-11 shows the standards for DON and ZEA in a ration for cattle in the Netherlands. The amount that can be in a singular feedstuff is among others determined by the amounts of remainder products in the ration. The " Productschap Diervoeder (PDV)" determined in 2004 that for singular feedstuffs 3x the standard can be followed for a ration (Qualityserie nr 96).

Control of DON and ZEA (and other field moulds) can be done through cultivation management, like plowing or removing stubble remainders. It is however not shown that corn varieties with a high fusarium resistance contribute to low amounts of DON and ZEA in the feed. Control of roquefortin C is possible through taking into account the silaging method and through feed management.

Table 7-11 Standards for mycotoxins in the ration of cattle (μg/kg)

Mycotoxine	Group of animals	Threshold for disapproval	Threshold to undertake action
DON	Calves up to 4 months	2.000	1.600
	Dairy cattle	3.000	2.400
	Other cattle	5.000	4.000
ZEA	Dairy cattle/weaners/calves	500	400
	Beef cattle	No threshold	No threshold

Source: Productschap Diervoeders

7.5.2.3 Nutrition

Corn silage is major part of cattle diets. Compared to other forages,corn silage has a high nutritive value, is an important source of starch and has compared to other as a forage crop is among others due to the high and constant nutritive value (VEM). Corn silage also fits well in a dairy cattle ration that contains grassland products .

(1) Nutritive value

Digestible organic matter contributes to the nutritive value of roughage as it consists of structural and non-structural carbohydrates, fats and proteins. Nutrients are released when digestible organic compounds are digested in the rumen and intestines and these are used for the formation of milk constituents and the formation of body reserves. (Table 7-12).

Table 7-12 Formation of milk constituents from feed

	Location of digestion			Used for milk constituents
Feed compound	Rumen	Intestine	Type of nutrient	Milk compound
Structural carbohydrates				
Cellulose	Acetic acid	-	Ketogenic	Milkfat
Hemicellulose	Acetic acid	-	Ketogenic	Milkfat
Pectin	Propionic acid	-	Glycogenic	Lactose
Non-structural carbohydrates				
Sugars	Butyric acid/propionic acid	-	Ketogenic/glycogenic	Milk fat/lactose
Starch	Propionic acid	Glucose	Glycogenic	Lactose
Fructosamine	Butyric acid	-	Ketogenic	Milkfat
Protein	Microbial protein	Amino acids	Amino genic/glucogenic[1]	Protein/Lactose
Fat	Triglycerides/fatty acid	Triglycerides/fatty acids	Ketogenic	Milkfat

Part of the amino acids is glycogenic and can be converted to glucose

(2) Analysis of nutritive value

In order to formulate adequate cattle diets it is important to sample and analyse corn silage for chemical composition and nutritive value.

① Structural carbohydrates

Carbohydrates from corn silage are by far the biggest suppliers of net energy to cattle . Carbohydrates can be distinguished into structural carbohydrates and non-structural carbohydrates. Structural carbohydrates mainly stem from cell wall compounds that contribute to the firmness of the plant. In a good developed crop harvested between 28 and 35% dry matter in the whole crop, cell walls contribute to approximately 40% of the digestible organic matter. Structural carbohydrates that contribute most to energy supply are cellulose, hemi-cellulose, and pectin. Non-structural carbohydrates are composed of starch, sugars, and fructosamines. The most important structural carbohydrates in corn silage are cellulose and hemi-cellulose that come from the leaves and stems. A large part of the cellulose and hemi-cellulose is digested in the rumen and part will leave the cow undigested. Degradation of cellulose and hemi-cellulose in the rumen mainly results in acetic acid which is absorbed in the blood through the rumen wall. Acetic acid is used for the synthesis of milk fat.

The crude fibre content and the content of the cell wall fractions (NDF, ADF, ADL) are measures for content of structural carbohydrates. The crude fibre content gives an indication on the amount of cell walls without distinguishing between different cell wall fractions. The cell wall fractions NDF, ADF, and ADL give insight on the type ture and relationships between cellulose, hemicellulose, and lignin (table 7-13).

Table 7-13 Composition of NDF, ADF, and ADL

NDF = Neutral Detergent Fibre	NDF = cellulose + lignin + hemicellulose
ADF = Acid Detergent Fibre	ADF = cellulose + lignin
ADL = Acid Detergent Lignin	ADL = lignin (indigestible)

② Non-structural carbohydrates

The most important non-structural carbohydrate in corn silage is starch which is stored in the grain. The starch content varies and is dependent on the hybrid and stage of maturity at harvest. The starch content can vary between 250 and 400 grams' starch per kg dry matter in a normal developed crop of corn silage that is in between 28 and 35% of dry matter content. The non-structural carbohydrates can be categorized in various fractions based on the rate digestion site of digestion in gastrointestinal tract GI-tract.

The first, category are sugars and readily rumen degradable starch (S+RRDS). These sugars and starches are degraded in the rumen at a rate of at least 12.5% per hour.

The second category is slowly rumen degradable starch (SRDS), which degraded in the rumen to propionic acid. The third category is rumen by-pass starch (RBS) which passes the rumen. Rumen by-pass starch is degraded in the small intestine in to glucose.

Compared to other starchy feeds, starch from corn silage is relatively slowly degraded in the rumen (table 7-14). Approximately 65 to 80% of starch from corn silage is slowly rumen degradable starch (SRDS) which degraded in the rumen; about 20 to 35% of the starch is rumen by-pass starch (RBS) and passes the rumen undegraded. The proportion of readily rumen degradable starch (S+RRDS) usually very small (<2%).

Table7-14 Ruminal degradation rate 1) of starch in corn silage compared with the degradation rate of starch in other feedstuffs

	Degradation rate in % per hour
Corn silage	7.9
Corn cob silage	7.7
Corn Cob Mix	7.2
Corn (dry grain)	4.0
Barley	21.3
Wheat	18.2

1) Degradation rates are averages derived from a number of studies.

③ **Protein**

Corn silage is high in energy but relatively low in crude protein and digestible protein available in the intestine (DPI). Because corn silage is high in energy and low in protein the rumen degradable protein (RDP-balance) is negative, which means that rumen degradable protein is limiting for growth of the rumen microbes.

Corn silage mainly has a high nutritive value due to high starch content.

The DPI is the amount of rumen by-pass feed protein and microbial protein synthesized in the rumen Microbial protein synthesis requires an energy source which the organic matter fermented in the rumen and a nitrogen source which is mainly ammonia that is released in the rumen with the degradation of rumen degradable feed protein, dietary non-protein nitrogen and urea that enters the rumen with saliva. The latter originates from ammonia that absorbed in the blood through the rumen wall and converted to urea in the liver. Urea is partly excreted in milk and urine but is also returned to the rumen via saliva. The energy source that is necessary for formation of microbial protein comes from the fermented organic materials. With corn silage, these consist out of digestible cell wall fractions and rumen degradable starch. Corn silage has a negative RDP-balance. A shortage of nitrogen (indicated by a negative RDP-balance) may limit organic matter fermentation in the rumen. For a good rumen function, maize silage based diets needs to be supplemented with protein sources which provide sufficient amounts of rumen degradable protein (e.g. soy bean meal, canola meal, alfalfa haylage)

④ **Fat**

Triglycerides and fatty acids that can be used for the formation of milk fat originate during the degradation of fat in the rumen and intestine. Corn silage contains only 3 to 4% fat. Fat from corn silage is therefore only contributing a little to formation of milk constituents.

⑤ **Minerals trace elements, and vitamins**

Minerals and trace elements play an essential role as functional groups in enzymes and antibodies and biochemical processes, e.g. in development of the skeleton, transport of ions through cell membranes, body fluids, and in the nerve functioning. The concentrations of minerals in corn silage are low. Therefore, corn silage based diets needs to be supplemented with minerals and trace element.

Table 3.4 Recommended minerals in the ration and presence of minerals in corn silage and silage grass

	Recommended amount per kg dry matter	Amount in corn silage per kg dry matter	Amount in silage grass per kg dry matter
Calcium (g)	3,5 – 5,5	1,6	5,4
Phosphorus (g)	3,0 – 3,5	1,9	4,1
Sodium (g)	1,0 – 1,5	0,2	2,7
Magnesium (g)	2,0 – 5,0	1,3	2,5
Potassium (g)	8	13	37
Chlorine (g)	3,5	1,3	12
Sulphur (g)	-	1,0	2,8
Iodine (mg)	0,6	0,1	0,2
Manganese (mg)	25	32	101
Zinc (mg)	25	38	46
Iron (mg)	-	152	532
Copper (mg)	10	3,6	8,5
Molybdenum (mg)	-	0,5	2,2
Cobalt (μg)	100	59	239
Selenium (μg)	150	23	49
KAV (mg)	-	230	560
Vitamin A (IE)	2000 – 5000	-	-
Vitamin D (IE)	300 – 500	-	-

Source: CVB en PV

With adding minerals and trace elements to a dairy cow ration it is necessary to consider that both an shortage and excess of minerals and trace elements can be harmful to the animal.

Vitamin deficiencies are rarely a problem in ruminants. A large amount of vitamins are produced in the rumen of ruminants, especially the vitamin B-complex, vitamin C, and K. Fat solvable vitamins A,D, and E are most essential for ruminants. Plant based feed contains no vitamin A. Plants do contain the pro-vitamin ß-carotene which is converted to vitamin A in the gastrointestinal tract. Vitamin D demand is dependent on the calcium and phosphor metabolism. Vitamin D can be synthesized by the animal itself in presence of UV-light.

Standard premixes that contain minerals, trace elements, and vitamin A, D, and E are usually added to a TMR. However, it is necessary to pay some special attention to appropriate mixing and distribution of the minerals, trace elements, and vitamin through the TMR.

⑥ Effective fiber, dietary physical structure

Dairy cows need sufficient structure in the ration of dairy cows to be able to ruminate and to stimulate rumen motility. Rumination stimulates saliva production. Sodium bicarbonate in saliva buffers the rumen pH. A rumen pH above 5.8 is required for a good rumen fermentation and fiber degradartion.

The physical structure value (or effective fiber) of corn silage is related to the cell wall content (NDF and crude fiber) and to a lesser extent to the theoretical length of cut (chop size). A higher cell wall content and larger chop size results in more effective fiber and dietary physical structure.

An increase of theoretical length of cut with 1 mm results in a 2% higher dietary physical structure with only marginal effects on rumen pH. Therefore, it is not recommended to increase the theoretical length of cut (chop size) to provide more effective fiber. Although, research showed that a greater theoretical length of cut (>9mm) resulted in more rumination activity per kg dry matter and per kg NDF, total chewing time (eating plus ruminating) did not change because a shift between eating activity towards ruminating activity. Moreover, a greater theoretical length of cut (chop size) resulted in a reduced dry matter intake, and more feed selection by the cows. More selection at the feed bunk resulted more feed waste and a lower feed utilization. A larger theoretical length of cut resulted in an improved fiber digestion, but in a reduced digestibility of the grain fraction. Ultimately a larger theoretical length of cut resulted in a reduced dry matter digestibility. As pointed out earlier, a larger theoretical length of cut resulted in a less dense packing of the silage clamps and hence a greater risk on air penetration and heating.

Chapter 8 2015-PPS2 Farm size development in China

8.1. About Principle Investigator

Ing. Alfons Beldman

Alfons Beldman has studied animal husbandry. He works for LEI Wageningen UR as a senior researcher and project manager mainly in projects related to dairy, sustainability and entrepreneurship.

Most projects are with strong involvement of sector stakeholders (processors, farmers).

Some of his activities:

Advisor Dutch Sustainable Dairy Chain. The Dutch Dairy Association (Nederlandse Zuivel Organisatie, NZO) and the Dutch Federation of Agriculture and Horticulture (LTO Nederland) have joined together in the Sustainable Dairy Chain. In this partnership the dairy processors involved work together to see to it that the Dutch dairy sector becomes the global leader in sustainability. For this reason, the Sustainable Dairy Chain has formulated a number of goals which are related to climate and energy, animal health and welfare, grazing and biodiversity and the environment. (2011 -).

Global Dairy Farmers: network of dairy farmers from all over the world and representatives from the supplying industry. GDF organizes a conferences and study trips for its members and produces a bi-monthly newsletter with current developments in the dairy sector worldwide. Member of the management team of GDF. GDF has organized trips to e.g. Australia, China, Europe, Russia, Argentina, Vietnam/Thailand.

8.2 Objectives of the study

Starting point of study was the assessment of the status quo in performance (economics, sustainability) of the different Chinese dairy farming systems. In the next step specific issues, like differences in management, use of technology to improve productivity, risks and a sustainable development within a 'from grass to glass' chain approach will be taken into account, resulting in a desired farm development in Chinese dairy. The first step was to conduct the study based on Dutch data. In the second step a survey with the help of Dr Junfei Bai and Liu Kai was conducted in China and an analyse was made based on Chines data.

The overall goal of the analyse was

- to get insight in performance of different farm types using performance indicators that fit with regional circumstances and, as a set of indicators, give an integrated picture of the overall performance.
- to get insight in differences in performance within farm types, to get insight in room for improvement

8.3 Main report of the research

For the overall picture of performance of a dairy farm indicators are required for:

- People (e.g. labour circumstances, safety, milk quality, use of antibiotics, animal welfare)
- Planet (e.g. losses of N and P, greenhouse gas emissions)
- Profit (e.g. productivity, gross margin, total costs)

The choice of indicators for this analyse was based on critical factors for Chinese dairy production, partly based on the white paper and the availability of data.

A survey was developed in cooperation with Dr Junfei Bai (CAU) and was conducted by CAU and SDDDC. The survey was an integral survey with collection of data on farm structure (herd, land, machinery, staff), farm management (feeding, manure, use of software), economics (loans/debts, gross margin) and performance (productivity, environment)

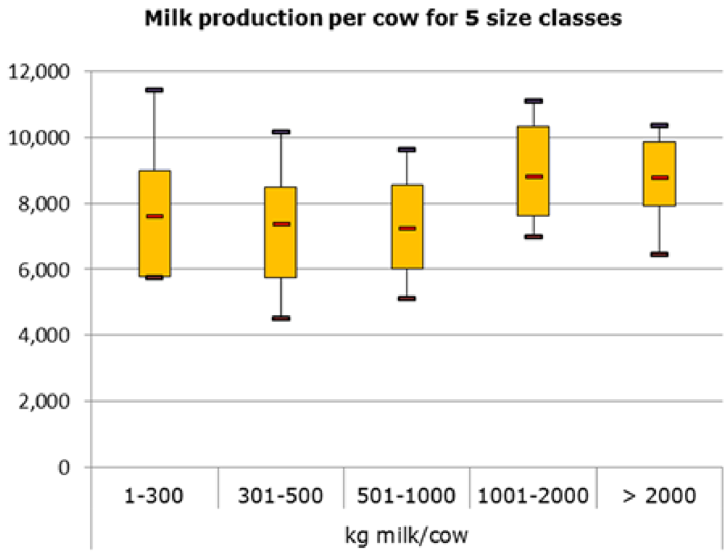
The survey was conducted in July – October 2015 by graduate students from College of Economics & Management (CEM), coordinated by Junfei Bai (CAU) and Liu Kai (SDDDC). The survey was conducted in the provinces Hebei, Tianjin and Beijing. The total sample of farms was 126. The first analysis was done by Shixian Zhai and Junfei BAI (both CAU), presented on December 7th 2015 at CAU. The dataset was further analysed by Wageningen UR by Co Daatselaar and Alfons Beldman, using the same farm size classes as in the analyse of the Chinese counterparts.

For most graphs and tables data of 90-100 farms could be used; only for feed costs and margin it was around 55.

The final performance indicators that were used in this study were:

- Milk quality (SCC, TBC, milk refusal)
- Milk yield/cow, cows/labor unit
- Milk price, feed cost, milk-feed margin, labour costs

The data was analysed and presented in 5 size classes of dairy farmers, showing the average (mark) result of the size class and de differences within the size class with boxes (25-75%) and whiskers (2.5 – 97.5%) as shown in the graph below.



The full report with all the graphs and the conclusions for each topic can be found in the appendix.

Within the survey also some data was collected on plans for investment and need and availability for loansBanks are main lenders, but also considerable number of other sources available

8.4 Conclusion

Summary of the main results

The majority of surveyed dairy farms had 300-1000 dairy cattle. On average the milk yield per cow was somewhat higher on larger farms.

Milk quality: Regarding milk quality there were found more negative outliers within the group of smallest farms. There were was not much difference between other groups. Also this survey shows that milk quality is a major issue: Nearly every farm has one or more refusals of milk. The main reasons for this are sensory evaluation, SCC and TBC. SCC and TBC are quite often above the international thresholds

Milk price: the average milk was prices nearly 4 RMB/kg (€0.50-€0.55; $0.60-$0.65). About 4.5 RMB/kg milk considered as appropriate (to cover the calculated costs). Larger farms have a higher milk price, but also somewhat higher feed costs.

Margin: The ratio milk price /feed costs is about 1.5, feed are clearly the major costs. This means that the margin is heavily influenced by variation in feed costs and cannot be controlled by the management. To compare the ratio milk/feed costs in the Netherlands is about 3.5. The margin is lower in the group of smallest farms, we did not find much difference between the other groups. In the data we found a tendency of less labour/kg milk on bigger farms. For other costs we did not see major differences between the different size classes. The calculated margin is rather low and does not include all costs. Taking into account the volatility of feed costs this means the systems are quite vulnerable. The survey also showed that quite a number of farms need loans for daily expenses. The top 3 of main problems to be solved according to the farmers were:

- Low milk price
- Independent test of milk quality
- Downturn of consumer market

Important conclusion is that the differences within farm types are big for almost all indicators, this suggest there is room for improvement on many farms and farm types.

Main overall conclusions

- The survey showed some differences between farm types: the group with smallest farms tends to have more outliers with milk quality, a lower milk price and lower margins. Differences between other groups rather small.
- The differences within groups are much bigger than the differences between groups. This shows that there is room for improvement.
- All farm types are vulnerable for volatile feed costs: feed costs are a high percentage of total costs and margins are relatively low.
- A large share of the farmers with smallest and largest scale farms expect that they cannot get the required/desired loans.
- With some additions this survey could give a balanced picture of the overall integral (triple P) performance of the different farm types. For the Chinese circumstances total costs, N and P efficiency and longevity should probably be added.
- The large differences within farm types show that there is room for improvement for many farms. Tools to achieve this improvement are:
    - o Use of bench mark tools to compare results of a specific farm with a peer group of farms with a similar farm structure;
    - o Exchange of best practices between farms e.g. by e-tools or in discussion groups;
    - o Suggestion is to use results of this survey to discuss in a workshop with e.g. dairy economists and/or farm managers if and how this type of information could be used.
- In order to assess integral performance (triple P) of different types of dairy farms a structured and continuous data collection is needed:
    - o Stratified sample of farms spread over different regions;
    - o Choice of right triple P indicators and aligned integral data collection;
    - o Continuous data collection (yearly of bi yearly) to be able to analyse trends.

8.5 Appendix

Farm Development Report: Differences between and within dairy farming systems

Chapter 9 2015-PPS3 Milk quality

9.1 About Principle Investigator

Ing. Pieter Hogewerf

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Short Curriculum Vitae

Education & work experience

BSc degree in Electro Technical Engineering, Hogere Technische School, HTS-Leeuwarden (The Netherlands)

Appointed as researcher since 2006 at Wageningen Livestock Research

Field of expertise

Research in the field of the application of animal identification, sensor development for detecting illness and oestrus in dairy cows, development of systems for automatic milking, development of research facilities for milking technology research and milking technology research

Scientific publications are available at

https://www.vcard.wur.nl/Views/Profile/View.aspx?id=430

9.2 Objectives of the study

Excellent quality raw milk is basis for high quality products. Demand for excellent quality is increasing but is only available on small percentage of Chinese farms. The quality shall be improved by on farm checks, also for farmer feedback: animal health, contamination milk, food safety, suitability for processing and long shelf life. The objective of this project is to develop practical guidelines for quality parameters & technology for measuring and ensuring farm milk quality and reviewing routines for: roughage production, feeding, animal health, milking, milk transport and on farm storage.

9.3 Main report of the research

A PPT overview of sensors used in Western European Dairy Farms.

The use of sensors in Dairy Farming

SDDDC project 2015

Ing. P. H. Hogewerf & Ir. A. H. Ipema , Wageningen UR Livestock Research

9.4 Conclusion

Some of the sensor systems used in the Western European Dairy Farms can also contribute to the improvement of the Chinese on farm raw milk quality. The sensor systems have to be integrated in the Chinese farm situations and the people have to learn (just as the Dutch farmers had to learn) how to interpret and use the information coming from those sensor systems. In the SDDDC project there has been limited progress on this part of the project especially because the Chinese project part was focussing on the quality monitoring and improvement during the milk manufacturing process.

9.5 Appendix

Report: The use of Sensors in Dairy Farming

Chapter 10 2015-PPS4 Farm management

10.1 About Principle Investigator

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Short Curriculum Vitae

Education & work experience

Msc degree in Animal Sciences and Business Management at Wageningen University

Appointed as researcher since 1994 at Wageningen Livestock Research

Field of expertise

Experienced specialist in farm management, information technology and quality management livestock production chains.

Scientific Publications are available at

http://www.narcis.nl/personpub/RecordID/PRS1306411

10.2 Objectives of the study

Objective of this project is to develop "Best Farm Management Practices" and knowledge to improve the lifetime performance of Chinese dairy cows. Specific focus will be the data collection and analyses on behalf of (individual) dairy production and reproduction results and the relationship with heat stress and longevity.

10.3 Main report of the research

Longevity and culling rate: how to improve?

Authors: Jelle Zijlstra*, Ma Jiayang**, Cao Zhijun** and Bennie van der Fels*

* Wageningen UR Livestock Research, Wageningen

** China Agricultural University, Beijing

10.4 Conclusion

10.4.1 Longevity as indicator

In the Netherlands high longevity is considered as indicator for health and welfare of dairy cows. In China longevity is more connected to sufficient available young stock and milk price. In case of lack of young stock and high milk prices, longevity will increase.

10.4.2 Reasons for culling

The most important culling reasons for dairy cows in both countries are almost the same. Reproduction problems, udder problems and hoof problems are in the top 4 in both countries. The difference in top 4 reasons are: digestive problems on place 2 in China and other (clustered) health problems on place 4 in the Netherlands.

10.4.3 Average productive life

Average productive life of dairy cows is 3.7 years in the Netherlands and first data of 19 Chinese dairy farms with an average herd size of 813 cows show an average productive life of 3.0 years. This productive life is exclusive the rearing period of about 2 years.

10.4.4 Recommendations to improve longevity

In both countries we suggest to improve longevity by:

a. Give the farmers clear insight into? their present longevity situation by benchmarking based on data about longevity, culling reasons and health problems.
b. Make a priority list of targets on animal health and welfare that will support minimizing involuntary culling (action plan).
c. Make a list of measures or best practices to adopt and apply them.
d. Monitor results and modify the plan to make a better fit to the specific farm situation.

10.5 Appendix: Longevity and culling rate: how to improve?

Authors: Jelle Zijlstra*, Ma Jiayang**, Cao Zhijun** and Bennie van der Fels*

** Wageningen UR Livestock Research, Wageningen*

*** China Agricultural University, Beijing*

10.5.1 The importance of longevity and culling rate

Animal health problems in dairy herds create extra costs, reduce milk production and will lead to high involuntary culling rates. In the Netherlands as well as in China dairy experts consider disease incidence rates and suboptimal culling rates as indicators of bottlenecks in dairy farm management. Improving health and animal welfare will result in longer living cows and this is why high longevity and lifetime production are seen as indicators for good dairy farm management. Improvement of this longevity is associated with lower culling rates.

Health problems are not only causing loss of profit but also disturb the workflow on the farm. Sick cows have to be treated and need extra attention until recovery. They will also cause infectious risks for the rest of the herd and should therefore be kept in isolation to avoid contamination.

The vision of farmers and consultants on longevity and culling is strongly influenced by views within the dairy industry and by the state of knowledge on animal health within the sector. These points are the reason that both topics evoke different associations in China and in the Netherlands. Table 10-1 lists some of these cultural differences.

Table 10-1 Differences about longevity aspects between China and the Netherlands

Aspect	China	Netherlands
Statistics	Start with pilot to collect data about culling rates and culling reasons	National statistics available about, longevity, lifetime production, culling rates and culling reasons
Available young stock	Shortage of young stock. Extra supply of heifers from New-Zealand and Australia	Farmers rear more young stock than needed for replacement. Part is exported outside EU.
Determining factors for longevity	Shortage of young stock and high milk prices stimulate farmers to keep suboptimal producing cows longer	High incidences of fertility, hoof and udder problems are constraining longevity
Longevity is indicator for farm management quality	Longevity became an important indicator for farm management quality in most large-scale dairy farms of dairy groups in recent years, while few individual farms take it as one of the important indexes.	Yes, this is the general opinion
Vision society	Animal welfare is becoming a public concern and more and more farm managers believe that cow welfare related with production efficiency.	Society desires good cow care resulting in more animal welfare and longer living cows
Financial incentives to increase longevity	In general: increasing longevity is not always expected to be profitable. It is more associated with lack of young stock.	In general: increasing longevity is considered to be profitable for the farmer Some dairy processors pay bonus on milk price to farmers with older cows

The Netherlands have a long tradition in aiming at high lifetime production of cows. For many decades, cows that pass the limit of 100,000 kg milk or 10,000 kg fat and protein are honoured at a party on the farm. And of course the farmer who cared for the cow, is part of this tribute. In the last five years, longevity receives extra attention from society because it is seen as an indicator of good care for cows. This is why the dairy sector is now aiming at increasing longevity by half a year during the period until 2020. This goal is part of the sustainability program of the united Dutch dairy companies and dairy farmer unions.

The goal of this paper is to present the results and experiences of collaborative work on longevity and culling rate on dairy farms. In 2015 Wageningen UR Livestock Research and China Agricultural University investigated the present situation on longevity and culling in both countries. Wageningen UR livestock Research summarized the efforts done in the Netherlands to come to an improvement program on longevity. China Agricultural University collected data of 81 farms with 113,367 dairy cows aiming at getting a better insight into culling practices on Chinese dairy farms.

10.5.2 Present situation in the Netherlands

The average age at culling (also defined as longevity) of Dutch dairy cows is 5.8 years[12]. In the last five years this figure has been quite stable. As mentioned before the Dutch dairy sector has the ambitious goal to increase it by six months in the period until 2020. Research showed that there is much variation between farms for this trait. The 25% farms with highest longevity have an average longevity of 7.1 years, whilst the 25% farms with lowest longevity have an average longevity of 4.9 years. This variation shows quite some potential to improve longevity.

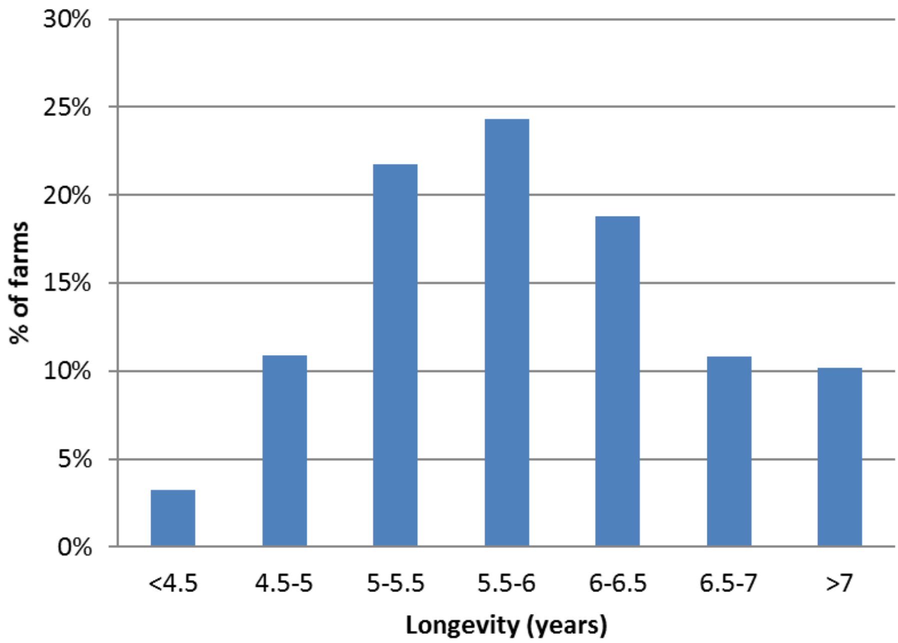

Figure 10-1 Distribution of Dutch farms across longevity classes[13]

[12],CRV, 2015

[13] Zijlstra et al., 2013 (data of Dutch farms during the period 2006 until 2012)

Figure 10-2 shows the division of culls by parity for Dutch cows on farms where culling reasons were recorded. The proportion of herds that record culling reasons has steadily grown in the last decade. In 2012 it was increased until 32% of all farms participating. The pattern shown by the bars in figure 10-2 is strongly connected to longevity. If longevity increases, a larger part of the culls will take place in higher parity numbers.

Figure 10-3 shows the reasons for culling on Dutch farms. Fertility, cell count/mastitis and legs and claws are the most frequently mentioned reasons for culling. The fourth reason 'fattening' is a kind of indirect reason for culling. Farmers will usually only fatten cows if they have decided to cull the cow at a later stage but like to combine milk production with fattening in the remaining productive life of the cow. The underlying reason for this decision can be e.g. infertility or disease incidences. Fattening is a kind of voluntary culling with an involuntary underlying reason. The same can be more or less true for other voluntary culling reasons like excess cows, low production and old age. This combined voluntary and involuntary culling reasons show that the differences between these two main categories are not easy to mark. However, Figure 10-3 shows very clearly that that fertility, mastitis, claws and miscellaneous health problems are the main reasons for involuntary culling on Dutch farms.

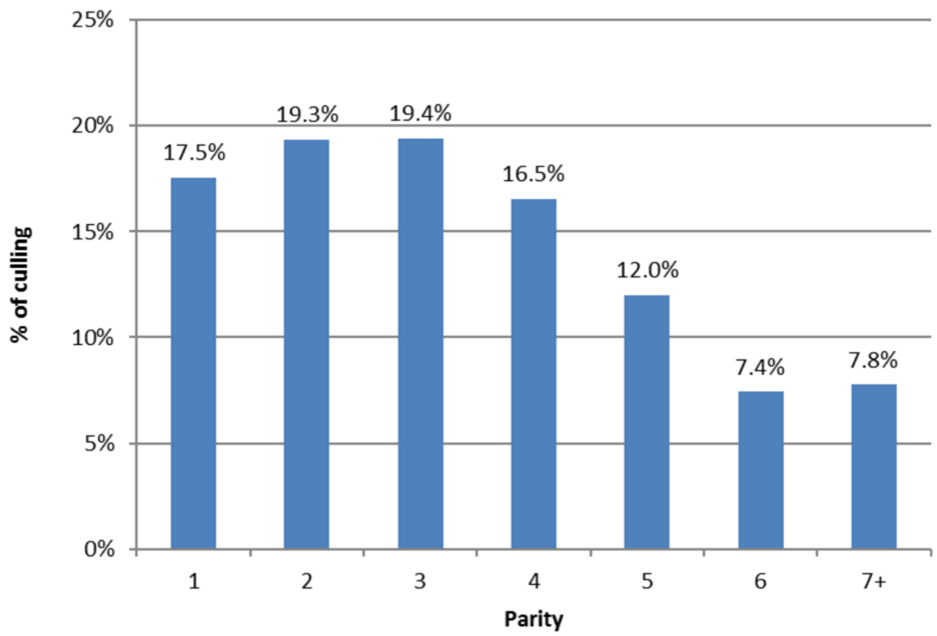

Figure 10-2 Percentage of culls by parity[14]

[14] Based on CRV data from 284,864 cows with minimal 87.5% Holstein breed, that were culled in the years 2007 until 2012.

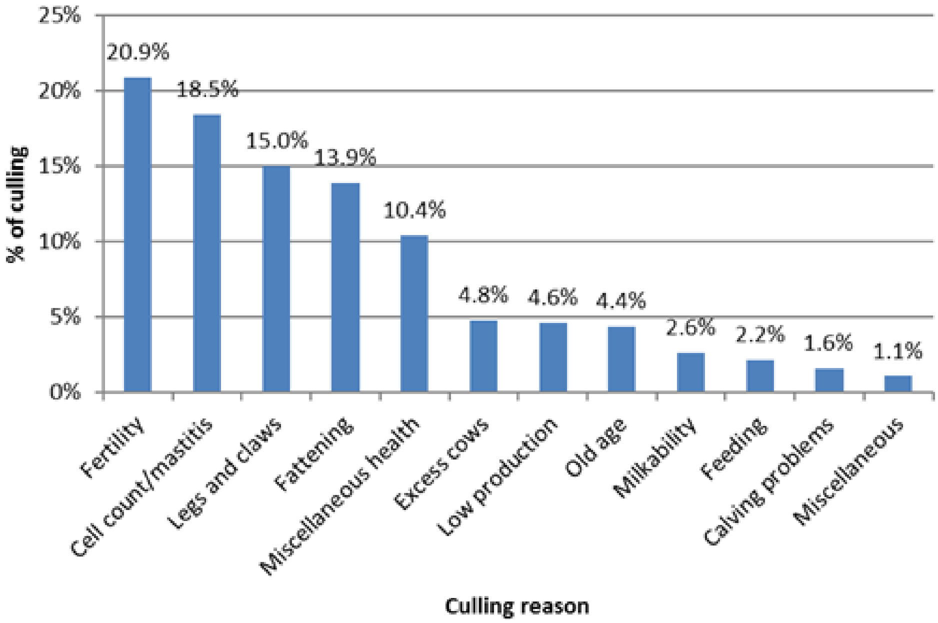

Figure 10-3 Reasons for culling[3]

10.5.3 Present situation in China

As mentioned before China Agricultural University collected data from 81 farms with 113,253 dairy cows (including dry and lactating cows) in total. The average herd size of these farms was 1398 cows.

Actually, the study comprised two main parts:

1) Individual cull information (farm visits and questionnaire)

2) Group dairy farm data

Firstly, participating dairy farms noted the reasons for culling of every cow that left the herd over a twelve-month period, starting in 2013. Secondly, these culling records provided primary culling reasons for each cow leaving the herd, resulting in a list of 50 culling reasons. Thirdly, each participating herd was sent a questionnaire asking for specific and detailed information on the management system of their herd. The questionnaire asked for details about the herd management system including fertility management, herd replacements, housing, milking, labour, and nutritional aspects. Tables 10-2 and 10-3 show a summary of the general statistics of the participating farms.

Table 10-2 General statistics for the provisional data (2014)

Total number of cows	113,253
Number of herds	81
Average herd size	1,398

Table 10-3 Number of farms and cows by different herd size (2014)

Range of herd size	No. of farms	No. of cows	No. of culled cows
>2000	16	72,069	15,557
1000-2000	13	17,001	3,984
500-1000	19	13,191	3,697
100-500	33	10,993	3,193
Total	81	113,253	26,431

Among these farms, 31 farms have lower culling rate than 23.3%. 76 of the farms recorded the parity of 25,917 culled cows and 65 farms recorded both the birth date and cull date for 23,881 cows. The average lifespan of culls is 4.9 years and the average productive life of these dairy cows is 2.7 years. Among the 65 farms, the 25% best performing farms have an average longevity of 5.6 years, while the 25% worst performing farms have an averaged longevity of 4.0 years.

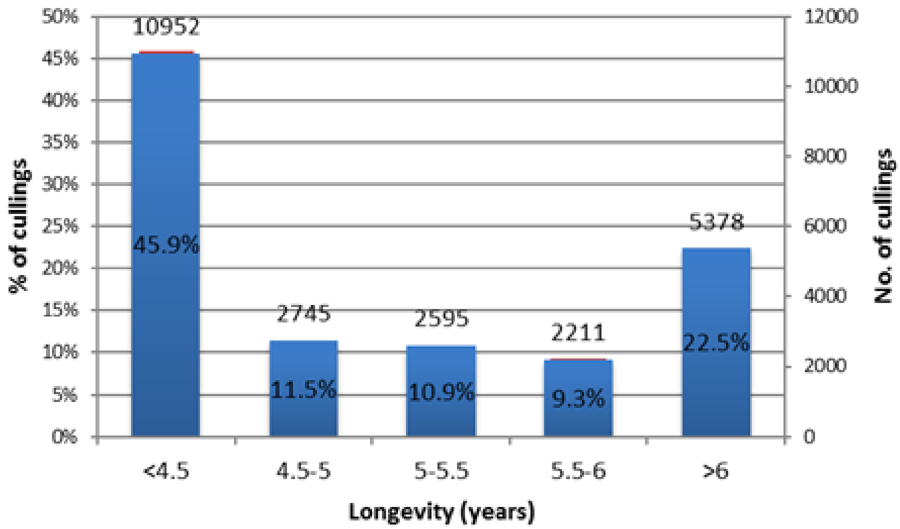

Figure 10-4 Distribution of 65 farms across longevity classes (2014)

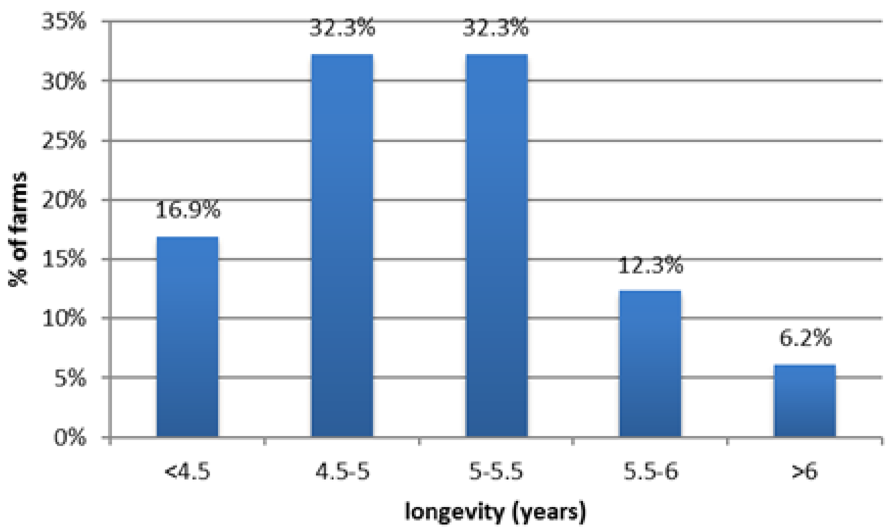

Figure 10-5 Distribution of 23,881 culling cows across longevity classes (2014)

Figure 10-4 shows that 6.2% of the 65 farms have a longevity of more than 6 years, while the cow longevity in 16.9% of these farms is lower than 4.5 years. 49.2% of the farms have a longevity of less than 5 years in figure 10-4, while figure 10-5 shows that more than 57% of culling cows leave the herd before they reach the age of 5 years old. This difference is caused by the larger average herd size of the farms in the two low longevity classes in figure 10-4. However, 22.5% of culling cows leave the herd after 6 years old.

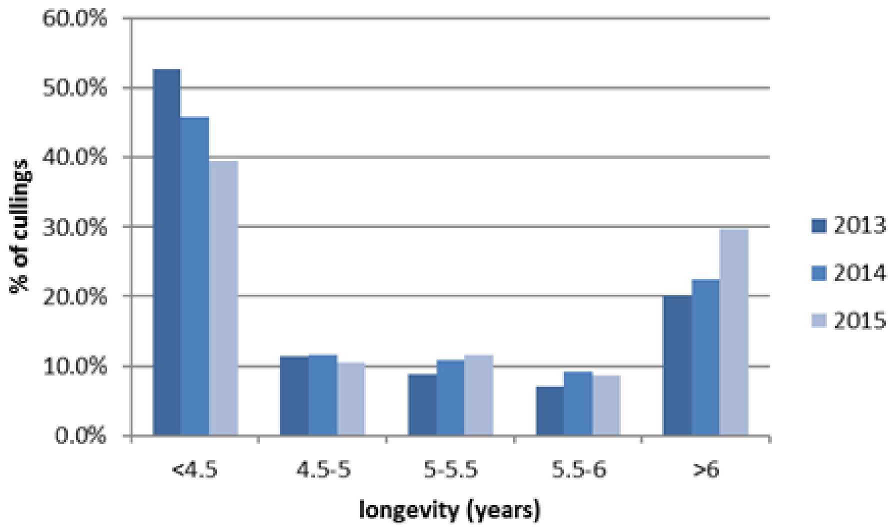

Figure 10-6 Distribution of culling cows across longevity classes in 3 years

In figure 10-6, the annual variation in the percentage of culling cows shows that more cows leave the herd after 6 years old and less cows were culled before the age of 4.5.

Figures 10-4 and 10-5 both show quite some potential to improve cow longevity in China, while figure 6, apparently, indicate the improvement in China cow longevity.

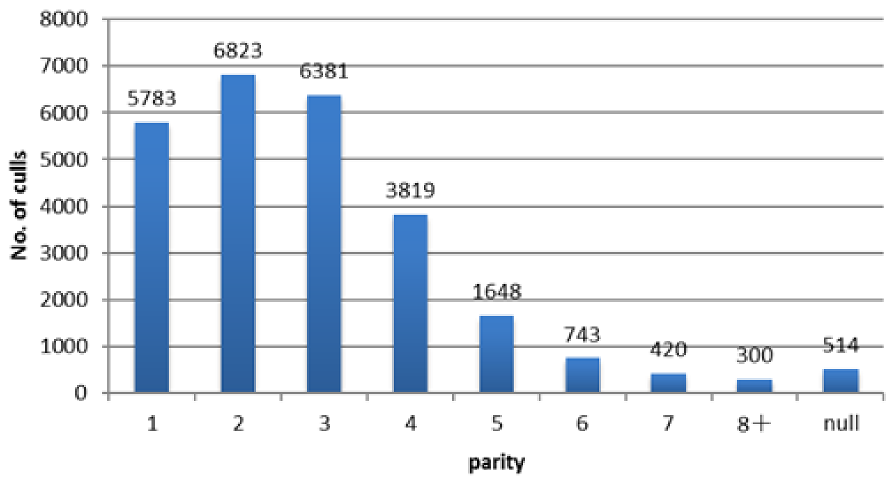

Figure 10-7 Number of all culls by parity (26,431 culls)

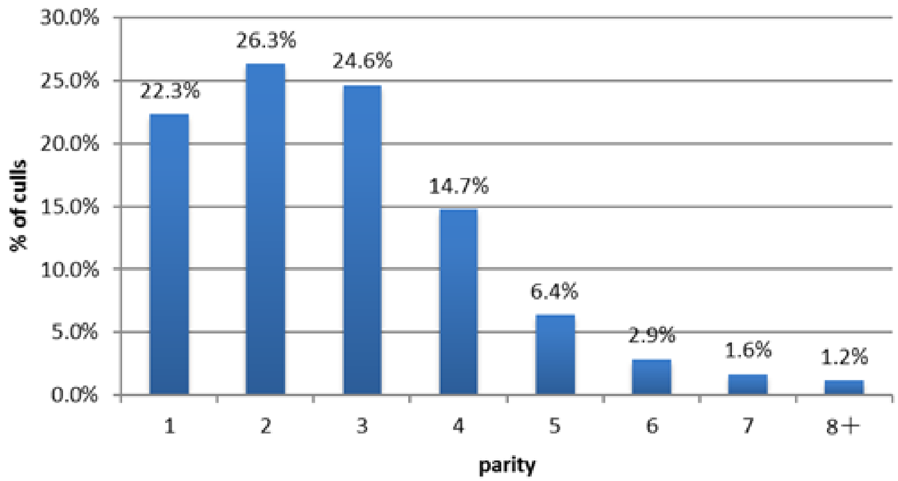

Figure 10-8 Percentage of all culls by parity (25,917 culls)

Figure 10-7 shows the distribution of 26,341 culls by parity and there were 514 culling cows with no parity recording. And figure 10-8 shows that among the 25,917 culled cows, more than 73% of them are culled in the first 3 lactations and the highest percentage of cullings is in parity 2 with 26.3% of all cullings. This division of cullings about parity leads to an average parity of culling of 2.7.

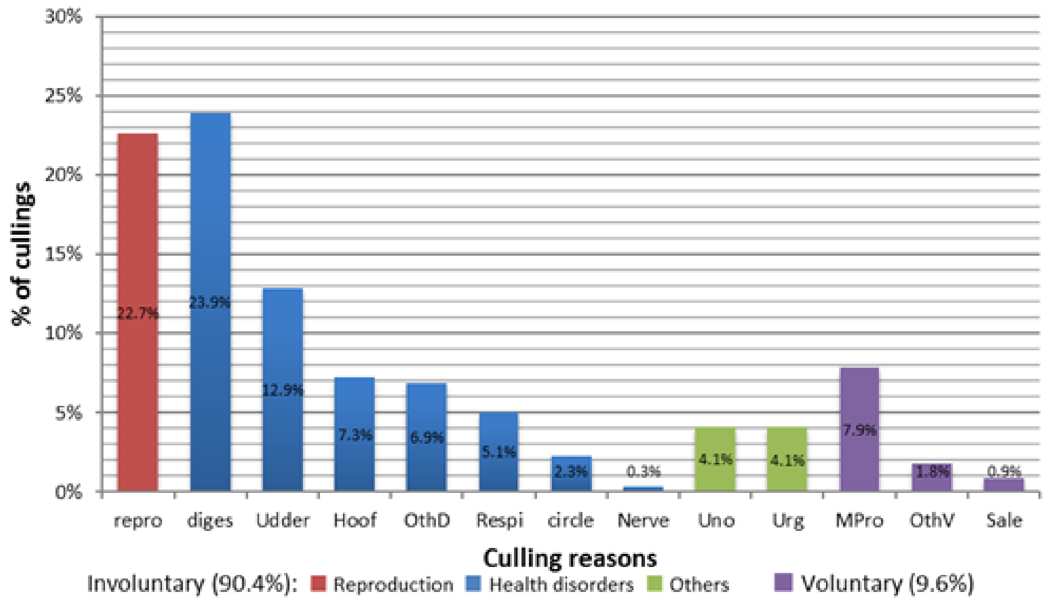

Figure 10-9 Reasons for culling (n = 25,920 cullings)

The most-frequent primary culling reasons were “Diges” (digestive system disorders and metabolic disorders), “Repro”(infertility or reproduction problems), and “Udder” (udder-related disorders, such as mastitis and teat injuries), which accounted, respectively, for 23.9%, 22.7% and 12.9% of total cullings. More than 81% of the cullings were declared in relation to health or reproductive disorders. Among these health related culling reasons, “Hoof” (hoof diseases) is also important to note, accounting for 7.3%.

However, a larger percentage of cows (4.1%) were removed from the herd due to “Uno” (unknown or unspecified) culling reasons. This may indicate missing data recording in cow files, particularly in some farms in China. There have been studies trying to ascertain why cows die on farm and from which diseases, but the information gathering is hindered by inaccurate and inconsistent data entry.

”Urg”(urgency)is also an important reason for culling. 4.1% of culled cows were sudden death or accidental injury, which exposed several problems in farm management.

Dairy cows, experiencing a disease or a reproductive disorder, are exposed to higher culling risks. This category of culls is usually designated as `involuntarily (or forced) culled cows', in contrast to all the other culls or sales, which are designated as `voluntarily (or selected) culled cows'. In Figure 10-9, only 8.83% were voluntarily culled cows and the highest voluntary or “selected” reason for culling is “MPro” (Low milk production) at 7.9%. That might show us farmers hardly cull their cows, unless the cows can’t bring benefits any more.

Possible reasons of fluctuation in culling rate may be the levels of milk production and milk and beef prices. Some farm managers suggest that these factors determine their culling decisions. So farmers may cull more cows in times of low milk production, low milk prices, and/or high beef prices. Some first results of our analysis show a negative relationship between milk price and culling rate. As the milk price drops, the culling rate increases. It means that farm managers tend to remove more cows from the herd in times of low milk price, due to unprofitable production.

10.5.4 International differences in average productive life

Table 10-4 Productive life of dairy cows in some countries specialized in dairy production

Country	Average productive life*
New Zealand	4.2
United Kingdom	3.9
The Netherlands	3.7
Poland	3.3[15]
France	3.2[16]
China	2.7[17]
USA	2.7[18]
Canada	2.7[19]
Israel	2.5

*Productive life = time span between first calving and culling
Source: FAO[20]

The great variation in Table 10-4 between all these countries in which Holstein-Friesian-type cows dominate the dairy cow population, suggest that farming systems play a role in determining longevity.

[15] Analysis of longevity and reasons for culling high-yielding cows, Adam Oler et al., 2012
[16] Reasons for culling in French Holstein cows, H. Seegers and F. Beaudeau, 1998
[17] Preliminary results Ma Jiaying and Cao Zhijun, 2016
[18] USDA. Dairy statistics[DB/OL]. 2013. Available at http://future.aae.wisc.edu.
[19] Source: CanWest DHI and Valacta
[20] FAO, 2013. Available at http://faostat.fao.org/site/569/DesktopDefault.aspx?PageID=569#ancor

Apparently dairy cows live longer in countries with grass-based farming systems (in New Zealand, United Kingdom and the Netherlands large part of the farms have grass based farming systems). One may add that the average production per cow per day is usually also lower on farms with grass based farming systems compared to cows in confinement systems. This could also lead to the assumption that these cows in grass based farming systems might be exposed to less metabolic stress resulting in a longer productive life. In USA, Canada and Israel the average production per cow per day is relatively high compared to the other countries in the table.

10.5.5 Sector approach to improve longevity in the Netherlands

As part of its Sustainable Dairy Chain Agenda the Dutch dairy sector has explored the possibilities to increase longevity by improving health and welfare of dairy cattle. A qualitative expert approach to appoint bottlenecks and solutions resulted in four key proposals to stimulate dairy farmers to increase in longevity at farm level[21]:

1. Create awareness about the added value of longer living cows by demonstrating results of farms that have increased longevity in the past and by using a tool that can forecast the financial results of adaptations in farming practices.
2. Develop a Plan-Do-Check-Adjust (PDCA) approach and teach farmers how to work at farm level on their bottlenecks to increase animal health and welfare. The PDCA approach requires from farmers to appoint the performance indexes they want to improve and challenges them to define targets, actions and deadlines to achieve the desired higher level of animal health and welfare. Working this way is expected to increase longevity and the financial results of the farm.
3. Create incentives to stimulate farmers to work on longevity. These incentives can comprise: workshops or trainings, bonus milk price or extra permits or licenses for farmers with higher average longevity level of the herd.
4. Organize trainings about better labour organization to avoid that a high work load will result in suboptimal animal care.

Till so far the dairy sector has made a start with implementing proposals 2 and 3. The other proposals are not yet turned into actions. Proposal 2 has also led to the development of nine key themes to improve health and longevity: longevity, production, culling, transition management, udder health, fertility, claw health, rearing of young stock and use of antibiotics. For each of these themes experts have recommended performance indexes that can be combined to two one-page reports: one report for annual evaluation and another report for monthly monitoring and evaluation. The performance indexes for this monthly report are listed in Table 10-5.

This report is made to provide farm managers with a quantified insight into the status of their farm for these themes. It also offers benchmarking possibilities by comparing farm figures with average performance indexes of peer groups. And in the Netherlands farmers, veterinarians and other

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[21] Zijlstra et al., 2013

consultants are also stimulated to formulate their own targets for some key performance indexes. These indexes are also valuable in the process to of the PDCA approach mentioned before. Improving indexes might require the introduction or adjustment of certain standard operating procedures that can support the right actions needed to move in the desired direction.

Table 10-5 Proposal for performance indexes for monthly farm report to monitor and evaluate dairy herd performance

	Theme	Performance indexes (farm averages)
1	Production	Milk production per cow (in real kg and in age and calving season corrected kg) Fat and protein content Urea content milk Milk production, fat and protein content, age and calving season corrected milk for 5 groups (categorized for days in milk) Idem for 3 groups categorized by parity (first calf, second calf and third calf and higher)
2	Transition management	% cows with %fat / %protein > 1.25 % cows scoring positive for ketose based on milk sample % cows with %fat / %protein < 1 % transition disease incidences
3	Udder health	Cell count bulk tank % mastitis incidences % successfully treated during lactation % New cows with increased cell count during lactation
4	Fertility	Days open Inseminations per cow
5	Claw health	% incidendes of claw disorders
6	Rearing of young stock	Age at first insemination Inseminations per heifer % diseases calves (during period 0-60 days)
7	Treatment with antibiotics	Animal days-dosage-number

10.5.6 Recommendations to improve longevity in China

In China, there is almost no attention to cow longevity. Farmers and farm managers are prone to put all their reflection and energy on how to make profits from cows and how to reach milk production targets. So the first thing we may do is communicating farmers and farm managers the importance of increasing longevity of cows.

Surveys show that the major reasons for culling are reproduction failure, mastitis, and lameness. Our data also show the similar conclusion that reproduction disorders, udder-related disorders, digestive system disorders and hoof diseases are assured known causes of culling in China, accounting for 68% of all cullings. For most average herds these are the areas requiring attention to improve herd longevity.

Before, we have mentioned that milk production influences farm managers' decisions. In fact, milk production is intimately connected to fertility and udder health. Hoof health and rumen health will also indirectly affect milk production. If a cow does not breed back and calve again, she will gradually (or suddenly) drop in production to levels beneath profitability. A mastitis cow produces less milk, if subclinical, or goes into the hospital group and incurs additional medical treatment and labor costs if clinical. Severe or chronic infections are costly.

If we want to increase cow longevity, we should improve the health and welfare of dairy cattle and minimize kinds of diseases of our cows.

The first step in improving longevity within a herd is to establish the current position by benchmarking key figures for the herd against group averages. Once a factor has been measured, it can be managed and priority areas can be identified for attention. Prepare a list of all culled cows in the last year. For each one identify the reason for leaving from the list. Then calculate some following indexes, such as:

1) Culling rate

   Take the total number of cullings over the 12-month period and divide by the rolling average herd size for the same period.

2) The percentages leaving for each of the main culling reasons

   Calculated by taking the totals for each reason divided by the total number of culls.

3) Average lactation age (average parity)

   Calculated using the latest set of records for the herd.

4) Involuntary or forced culling rate

   The total number of cullings for an involuntary reason divided by the rolling average herd size.

Using the calculated figures for the herd and comparing data with group averages, a farmer will find the relative situation. If this relative position is suboptimal, then he can select a herd strategy to achieve his optimal position (reduce overall culling rate or reduce the level of a specific reason). All the problems cannot be fixed at once. Draw up a priority action list and address the biggest problems first:

- Identify the major reasons cows are getting culled and generate possible solutions. If all culling reasons are higher than expectation, start from focusing on one or two to determine causes and begin action plans to correct the problems. Further investigation is needed once a category has been selected to better understand reasons for culling and generate possible solutions
- If the total involuntary culling rate is greater than average, or the involuntary cullings are over 60%[22] of all cullings or if the involuntary culling rate is higher than the farm target, there is opportunity to improve it. We can set an achievable guideline. However, the goal should be to minimize the involuntary cull rate.
- Cows leaving the herd when less than 30 days in milk (DIM) usually are cows that have died or have serious metabolic or infectious disease problems at calving. It is important to distinguish between cows that are culled and cows that die. Analyse the records to determine early

[22] UK MDC, Longevity - controlling culling to improve herd profitability. Publication - Milk Development Council, 2000.

lactation cullings and the broad categories causing cows to leave. The farmer should develop guidelines to support decisions about culling, especially for decisions in early stage of lactation (e.g. less than 100 DIM)

- Develop a farm specific action plan and set up a monitoring plan. Work with the appropriate team of advisors and employees to develop an action plan based on your on-farm investigations and also some key monitors to determine if your plan is working. Make modifications to the plan if it does not deliver the expected results.

10.5.6 Conclusions

1) Longevity as indicator

   In the Netherlands high longevity is considered as indicator for health and welfare of dairy cows. In China longevity is more connected to sufficient available young stock and milk price. In case of lack of young stock and high milk prices, longevity will increase.

2) Reasons for culling

   The most important culling reasons for dairy cows in both countries are almost the same. Reproduction problems, udder problems and hoof problems are in the top 4 in both countries. The difference in top 4 reasons are: digestive problems on place 2 in China and other (clustered) health problems on place 4 in the Netherlands.

3) Average productive life

   Average productive life of dairy cows is 3.7 years in the Netherlands and first data of 19 Chinese dairy farms with an average herd size of 813 cows show an average productive life of 3.0 years. This productive life is exclusive the rearing period of about 2 years.

4) Recommendations to improve longevity

   In both countries we suggest to improve longevity by:

   a) Give the farmers clear insight into? their present longevity situation by benchmarking based on data about longevity, culling reasons and health problems.
   b) Make a priority list of targets on animal health and welfare that will support minimizing involuntary culling (action plan).
   c) Make a list of measures or best practices to adopt and apply them.
   d) Monitor results and modify the plan to make a better fit to the specific farm situation.

Acknowledgement

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Chapter 11 2015-PPS5 Manure handling

11.1 About Principle Investigator

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Short Curriculum Vitae

A short impression

After finishing secondary education, I moved to Wageningen Agricultural University where I qualified cum laude with an MSc in environmental sciences in 1996. Later on I finished my PhD thesis at the same university. Since then, I have been working at several companies and research institutes.

During my professional career, I have focused on solid waste management (e.g. manure) and abatement of air-borne emissions, both in agricultural and industrial settings.

I am driven by the desire to find practical solutions for complicated problems, building on my R&D background as scientist and process engineer.

Selected peer-reviewed publications on manure treatment

5) Vu, P.T., **R.W. Melse**, G. Zeeman, P.W.G. Groot Koerkamp (2016). Composition and biogas yield of a novel source segregation system for pig excreta. Biosystems Engineering Vol 145 pp 29-38.
6) **Melse, R.W.**; M. Timmerman (2009). Sustainable intensive livestock production demands manure and exhaust air treatment technologies. Bioresour. Technol. Vol 100 No 22 pp 5506-5511.
7) **Melse, R.W.**; Verdoes, N. (2005) Evaluation of four farm-scale systems for the treatment of liquid pig manure. Biosyst. Eng. Vol 92 No 1 pp 47-57.

For a complete list of my publications, please visit:

https://scholar.google.com/citations?user=3o8RPM8AAAAJ

11.2 Objectives of the study

The aim of this work package is to analyse and identify sustainable manure treatment techniques that are suitable for application in the Chinese dairy industry. These techniques must be able to further close the mineral cycles (N, P, K), comply with Chinese (legal) requirements and at the same time be economically feasible (i.e. not lead to extreme raise of milk price).

11.3 Main report of the research

As a first step, two fact-finding missions were conducted. Researchers from China Agricultural University and Wageningen UR Livestock Research visited eight dairy farms and biogas installations in Beijing Municipality, Hebei Province and Shanxi Province. One of the visited locations was the SDDDC demonstration farm (Zhongdi Farm).

Furthermore, knowledge exchange meetings took place with staff and students at the China Agricultural University and at the Chinese Academy of Agricultural Sciences. Also we hosted Assoc. Prof. QIAO Wei of CAU when he visited the Netherlands and paid a visit to several Wageningen UR environmental laboratories and several livestock research facilities.

Finally, a calculation tool for manure separation was made. This spreadsheet (both in English and Chinese language version) can be used to quickly estimate amounts and nutrient levels of liquid and solid manure fractions, produced by mechanical separation using a screw-press.

11.4 Conclusion

Generally speaking, cattle slurry and anaerobic digester effluent are valuable fertilizers that can be employed in feed and food production in an environmentally and economically justified way.

However, when large numbers of animals are concentrated in a relatively small area (as is the case in parts of China and The Netherlands), the available area of agricultural land may be insufficient for manure application. In that case, to avoid over-fertilization, the surplus manure should be transported to a region where it can be used responsibly as fertilizer on agricultural land. In our opinion, further research and extension should be aimed at increasing the manure nutrient efficiency. This means that losses to the environment (e.g. to groundwater tables, surface water, air) are minimized.

We propose to establish recommended and maximum nutrient application rates for nitrogen and phosphate from animal manure in China. Experiences in the Netherlands and other countries show that a combination of legislation and enforcement is essential to achieve the set goals and to prevent dumping of large manure volumes on small areas of agricultural land.

However, chemical analyses of the nutrient (N and P) contents of cattle slurry, anaerobic digester effluent, solid and liquid fractions and other manure products, are often lacking at the moment. Although these values are essential for the calculation of accurate crop specific fertilization rates, or the calculation of how much manure can be adequately utilized per mu (15 mu = 1 hectare). The development and dissemination of knowledge on the nutrient levels in organic fertilizers in relation to the nutritional needs of crops is highly desirable. This includes the interpretation by farm managers of the results of chemical analysis of organic fertilizers and soils.

Finally, we recommend to formulate farm specific ‘Manure Nutrient Management Plans’ for new large-scale livestock farms, in order to prevent the occurrence of manure surpluses at large-scale dairy farms without enough arable land. One of the main elements in such a plan is a calculation on how much manure and nutrients are produced per year, how this manure is treated or utilized on the farm or what happens with it when it is transported to other farms or companies. Plans for application of manure to crops must include a calculation of manure and nutrients application rates. This means that an inventory has to be made of regional opportunities for manure nutrient utilization in cattle feed and food crop production, prior to establishing a new livestock farm.

11.5 Appendix

11.5.1 Manure Management 2015 Progress Report

Impression of Datong Sifang Dairy Farm, Datong, Shanxi Province, China

11.5.1.1 Introduction

Sino-Dutch Dairy Development Centre (SDDDC)

In November 2013, China Agricultural University (CAU), Wageningen UR (WUR) and Friesland Campina launched the Sino-Dutch Dairy Development Centre (SDDDC) in Beijing. The objective of the Centre is to improve dairy production, safety and quality levels throughout the entire dairy chain in China. The SDDDC's activities focus on sharing Dutch dairy expertise with Chinese experts and decision makers in dairy research and the dairy industry.

Public-Private-Partnership (PPP) Sino-Dutch Dairy Development Centre

The activities of the Expertise Centre entail Research, Innovation, Education, Training and Demonstrations. Within the PPP the focus lies on fundamental and applied research:

- Perform high-profile Research Projects on current Chinese dairy safety and quality issues and involve and engage relevant Ministries
- Support an Expertise Centre in China where safety and quality systems can be put into practice
- Cultivate talent, by facilitating student and faculty exchange and setting up training courses

Five Work Packages (PPP's) within SDDDC

The following Wageningen UR projects were formulated for 2015:

- WP1: Corn/hay production and feeding efficiency
- WP2: Farm size development in China
- WP3: Milk quality
- WP4: Farm management
- WP5: Manure Management

This progress report describes the findings and activities within WP5 "Manure Management" for the year 2015 (Project Leader: Dr. Roland W. MELSE). This project is linked to the CAU-project 2015-R2 "Sustainable Dairy Manure Management" (Project Leader: Dr. DONG Renjie).

11.5.1.2 Background

(1) Rapid growth and upscaling of the dairy sector in China[23]

Considering income levels, population, urbanization and consumer preferences, it is estimated that the annual growth rate of dairy cattle number will be 5 – 7.5 % in China, so the total number of dairy cattle may reach 13.5 to 16 million in 2016 and 2020 respectively.

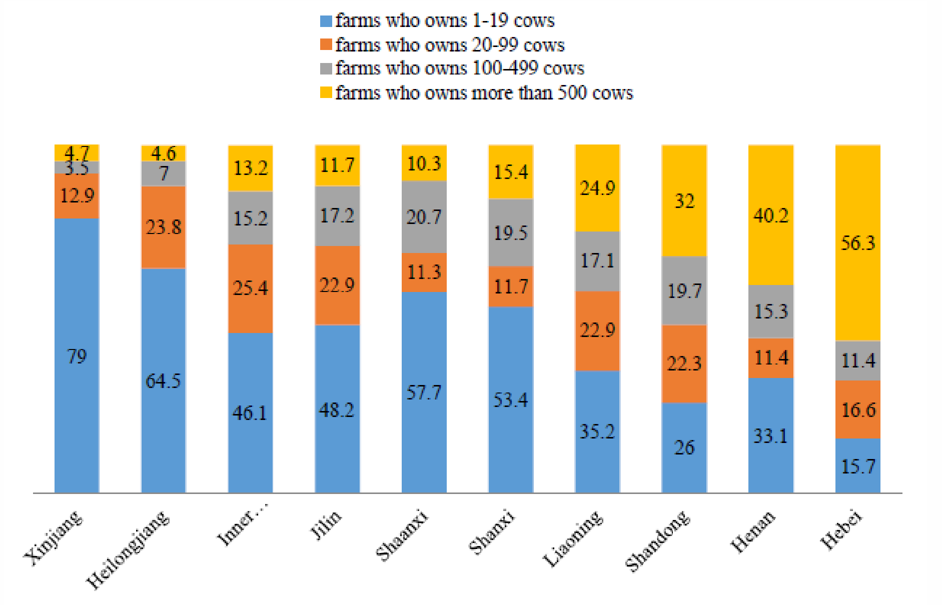
In traditional dairy farming (with a cow yard outside the barn), the cow yard is a prominent agricultural nonpoint source of pollution. Most cow yards don't have facilities to prevent liquid waste from leaching, sewage drainage or rain water and sewage separation measures, so that the nitrogen, phosphorus and other pollutants from urine and manure seep, leak or flow and thus pollute the environment.

In 2014, the Ministry of Agriculture continued to launch standardized large-scale dairy farm construction projects across China, and promoted demonstrations of standardized livestock farming. At the same time, some large dairy enterprises and large scale farming enterprises are accelerating construction of their dairy farms. These include more and more large-scale dairy farms which own thousands and even tens of thousands of dairy cattle. In recent years, due to the impact of rising feed costs, labor shortages and low efficiency, small household farmers are gradually tending to establish farming communities or household farms and most will choose to exit the dairy farming industry. Therefore, the development of large-scale farms will continue and is expected to account for 50 % of dairy farms in 2020. In Table 11-1 the characteristics of the major types of dairy farms are summarized; in Figure 11-1 the distribution of farm scales is shown for the regions in China.

[23] Source: Li Shengli, Liu Kai, Liu Xiao (eds). 2014. White paper on China Dairy (2014). Other authors: Alfons Beldman; Bai Junfei; Cao Binbin; Cao Zhijun; Du Wen; Fang Xiangming; Guo Huiyuan; Guo Pei; Han Beizhong; Hu Dinghuan; Jeroen Heck; Kees de Koning; Lieuwe Montsma; Ren Fazheng; Wang Wenxin; Wang Yajing; Xia Jianmin; Yang Hongjian; Yao Kun. Sino-Dutch Dairy Development Centre.

Table 11-1. Scale and organization of three major types of dairy farming in China (source: Li Shengli *et al.*, 2014)

	Small Household Farmer	Farming communities (cooperative dairy farms)	Large-scale dairy farms
Cow numbers	5-30	>100	>200
Average annual milk production (t/cow)	4-5	>5.5	>6.5
Ratio(%)	40	30	30
Method of feeding management	Cows raised in backyard	Small household farmers bring their cows together to raise in an area with a milking parlor	Cows belong to one owner and are grouped, raised by laborers
Main roughage	Primarily low-quality forage Corn Stalk with no silage	Forage quality better than household farmers, corn stalk, corn stalk silage, sheep grass	Corn silage, imported or domestic alfalfa and sheep grass
Milking	Milk in milk collection station	Milk in milking parlor	Milking parlor
Manure treatment	Compost	Compost	Compost, biogas



Source: "China Dairy Yearbook" over the years.

Figure 11-1 Proportions (%) of different dairy farming scales in the top ten provinces and autonomous regions in terms of dairy cattle (source: Li Shengli *et al.*, 2014).

In the past, most dairy farmers were backyard farmers with 3-10 cows. Fermenting and composting manure to use as fertilizer for crops was a virtuous circle and a quite environmentally-friendly approach. However, as the size of farms expands, it becomes more difficult to discharge and dispose of the waste and manure. More and more manure from bigger scale dairy farms has been discharged onto public land, and is polluting the environment. New regulations (see below) makes the newly built dairy farms feel pressure about dealing with environment control.

(2) Observations and recommendation from SAIN

Several years ago a China-UK Sustainable Agriculture Innovation Network (SAIN) was established to provide a framework for the development and implementation of collaboration on environmentally sustainable agriculture. Within this framwork several reports and papers were published. One of the papers was on "Improving Manure Nutrient Management in China", of which the main observations and recommendation are summarized below[24]:

- 3060 million tonnes (fresh weight) of livestock manure was generated in China in 2010. The N, P_2O_5 and K_2O content of these manures is estimated to represent *ca*. 14 million, 10.2 million and 12.0 million tonnes respectively, which is worth *ca*. 201,300M RMB (based on 5.4, 5.5, 5.8 RMB per kg N, P_2O_5 and K_2O, respectively),
- Manure is commonly over-applied to horticultural crops, particularly greenhouse vegetables and fruit, which causes negative environmental impacts,
- The barriers for effective management of manure, compost and digestate include lack of labour to transport and apply to the field, lack of knowledge of the nutrient content and availability and inadequate labelling of e.g. composted manure products;
- The pathways for improved manure nutrient management include:
    - Retaining nutrients through the manure management continuum,
    - Using an integrated nutrient recommendation system,
    - Generating knowledge of the nutrient content and nutrient availability of manure, compost and digestate,
    - Ensuring CAFOs have manure nutrient management plans for utilisation in the local area (planning regulations),
    - Encouraging and incentivising improvements in other infrastructure, e.g. to facilitate mechanised transportation and spreading of manures.

(3) New regulations on prevention and control of pollution from CAFO's

New national regulations on large-scale livestock farm pollution control came into effect in 2014. The new regulations demand an environmental impact assessment plan to be written and also require the construction of facilities for pollution prevention and control. Furthermore, the new regulations state that the central government encourages and supports the elimination and utilization of animal wastes by integrating animal production and crop production. When manure or manure products are used for fertilization of crops, the application shall not exceed the carrying capacity of the land in order to prevent environmental pollution. However, in these regulations no numbers are given on maximum amounts of nutrients (N or P) or manure that may be applied to the land. In order to reduce environmental pollution, we feel that strict regulations are necessary that outline how much manure can be adequately utilized per mu, and therefore is allowed to be applied[25].

[24] Source: SAIN Policy Brief No. 6.pdf Improving manure nutrient management towards sustainable intensification in China, Authors: David Chadwick, Chen Qing, Tong Yan'an, Yu Guanghui and Shen Qirong, July 2012.

[25] 15 mu = 1 ha = 10.000 m^2.

11.5.1.3 Activities carried out in 2015

(1) Fact-finding missions

In June and September 2015, two fact-finding missions in the field of WP5-Manure Management were conducted. Researchers from China Agricultural University and Wageningen UR Livestock Research visited eight dairy farms and biogas installations in Beijing Municipality, Hebei Province and Shanxi Province. One of the visited locations was the SDDDC demonstration farm (Zhongdi Farm). The locations were selected in consultation with the staff of SDDDC and China Agricultural University. In Table 11-2 the visited farm locations are shortly described.

Table 11-2 Field visits in June and September 2015, for more detailed information: see Annex 11-1.

Nr	Farm/Location	Numbers of milking cows / total cattle
1.	Huachen Dairy Farm, Lisui Town, Shunyi District, Beijing Municipality	160 / 350
2.	Zhongdi Farm (SDDDC), Zhaojiayu village, Dasungezhuang Town, Shunyi District, Beijing Municipality	2.200 / 4.400
3.	Baoding Shuangfeng Dairy Farm, Qingyuan County, Baoding City, Hebei Province	460 / 1.000
4.	Yiren Cooperative Dairy Farm, Dinghzou City, Hebei Province	540 / 1.200 (27 farmers)
5.	Lvhe Dairy Farm, Beijing Municipality	1.600 cattle
6.	Beijing Yingherui Environment Ltd., Biogas plant, Beijing Municipality	Biogas plant on solid cattle manure
7.	Zhangjiakou farm (Modern Farming Saibei Farm and Biogas plant), Hebei Province	4 x 10.000 cattle
8.	Datong Sifang Dairy Farm, two locations, Datong, Shanxi Province	700 / 1.200 and 2.200 / 6.000

The farms that were visited varied in livestock numbers as well as in the applied manure treatment technologies, ranging from no treatment at all to slurry flushing systems, biogas technology, mechanical slurry separation and tunnel composting of the solid fraction. In the next chapters the main findings from these visits are presented and discussed.

(2) Knowledge exchange meetings

Knowledge exchange meetings took place with staff and students at the China Agricultural University (September 23rd, 2015, Assoc. Prof. QIAO Wei) and with staff and students at the Chinese Academy of Agricultural Sciences (September 18th, 2015, Prof. DONG Hongmin). During these meetings, both the Dutch and the Chinese situation regarding manure nutrient management, gaseous emissions and environmental policy were discussed.

A return visit of Assoc. Prof. QIAO Wei of CAU to the Netherlands on September 30th/October 1st, 2015 made it possible to visit several Wageningen UR environmental laboratories and several livestock research facilities (research accomodation CARUS in Wageningen and dairy cattle demonstration farm

‘De Marke’ in Hengelo, Gld).

(3) Calculation tool for manure separation

One of the basic technologies for manure (slurry) treatment is the separation of slurry (or digestate) into a solid fraction and a liquid fraction. Often a screw-press is used (see next chapter) the produced solid and liquid fractions can be used for further processing or can be used directly for fertilization. Although separation can be regarded as a simple technique, it is often not entirely clear how the nutrients and dry matter are distributed between the two fractions.

In order to provide more insight into nutrient concentrations and total amounts of nutrients, dry matter and mass flows, a calculation tool was developed. The spreadsheet can be used to quickly estimate amounts and nutrient levels of liquid and solid manure fractions, produced by mechanical separation using a screw-press. In this way, the spreadsheet may help farm managers that are thinking about buying slurry separation equipment by predicting what products they can expect. Furthermore, farms that already have separation equipment can get insight in how increasing or decreasing the separation efficiency will affect the amounts and nutrient contents of the products.

The inputs of the spreadsheet (that can be changed by the end-user) are:

- the characteristics of the slurry (contents in kg/ton);
- the performance of the screw-press, as defined by mass separation efficiency (%) and dry matter content (kg/ton) of the solid fraction produced;
- the manure production per year (number of cows and slurry production per cow per year).

Using this data, the spreadsheet calculates the nutrient contents and amount of the solid and liquid fractions, including the distribution (in%) of nutrients between the fractions. Furthermore, a mass balance for a one-year period is shown.

The spreadsheet calculation tool will be made available on the SDDDC website (http://sdddc.org), both in an English and a Chinese language version.

11.5.1.4 Results of fact-finding missions

(1) Manure collection, treatment and storage

The most advanced manure treatment systems encountered where those with automated scrapers on concrete floors and flushing of the scraped manure through channels with the liquid fraction from manure separation (location 2 and 8) or with water (location 3 and 5), biogas production (location 6 and 7) and slurry separation with screw press filters (location 3, 5, 6, 7 and 8). At one location (location 2) we encountered the combination of an inclined screen separator with a screw press filter. The solid fraction from manure separation, fresh (most farms) or composted (location 8), is either used for bedding or sold to vegetable growers. At one location (location 5) there was no demand for solid or liquid fraction, due to absence of sufficient vegetable growers nearby. However, separation was applied. The liquid fraction from slurry separation is mostly stored in open lagoons for subsequent use as a liquid fertilizer. At many farms these types of lagoons are not covered. At Zhongdi Farm most lagoons are covered with a floating cover, which will substantially reduce emissions of ammonia.

In figure 11-2 to figure 11-7 some pictures are given that show the present equipment and facilities on some of the farms.

Figure 11-2 A typical large-scale dairy farm; cubicles with solid manure bedding and scraped concrete floors, Datong Sifang Dairy, Datong, Shanxi Province.

Figure 11-3 Horizontal biogas reactor, partly below ground, at Modern Farming Saibei Farm, Hebei Province.

Figure 11-4 Combination of an inclined screen separator and a screw press filter for slurry separation, Zhongdi Farm, Beijing Municipality.

Figure 11-5 Solid manure from slurry separation is used as bedding material in the cubicles, Modern Farming Saibei Farm, Hebei province.

Figure 11-6 Covered lagoon storage of liquid fraction from slurry separation, Zhongdi Farm, Beijing Municipality. Note the gas production under the cover.

Figure 11-7 Tunnel composting of solid manure fraction, Datong Sifang Farm, Datong, Shanxi Province. Composted manure is sold for 40 – 50 RMB (≈ 6 – 7 Euro) per ton.

(2) Manure application

Most cattle farms do not own agricultural land, so manure has to be sold and/or transported to other arable farms. Solid manure is normally transported in open trucks and mostly used as fertilizer for vegetable crops. Liquid manure is applied to agricultural land either by spreader trucks (see Figure 11-8 for an example) or by irrigation.

Figure 11-8 Filling the manure spreader with the liquid fraction from digestate separation, Modern Farming Saibei Farm, Hebei Province.

(3) Nutrient flows and distribution between solid and liquid fraction

When cattle slurry (with a dry matter content of approx. 10 %) is separated with a screw press filter, the mass of the input slurry (100 %) is divided into 15 – 25 % of solid fraction by mass and 75 – 85 % of liquid fraction by mass. The solid fraction has a dry matter content of 20 – 40 % and the liquid fraction has a dry matter content of 5 – 7 %.

Extensive testing of different screw press filters with cattle slurry in the Netherlands[26] revealed that approximately 15 - 20 % of the nitrogen (N) and 20 - 35 % of the phosphate (P_2O_5) is transferred to the solid fraction, depending on the initial slurry dry matter content and the performance of the screw press separator. Consequently, 80 - 85 % of the nitrogen and 65 – 80 % of the phosphate remain in the liquid fraction which also constitutes the largest volume share.

For more information, please consult the Spreadsheet Calculation Tool for slurry separation with a screw press filter, described in 11.5.1.3, paragraph (3).

[26] Schröder, J.J.; Buisonjé, F.E. de; Kasper, G.J.; Verdoes, N.; Verloop, K. (2009). Mestscheiding: relaties tussen techniek, kosten, milieu en landbouwkundige waarde. Wageningen : Plant Research International, 2009 (PRI Rapport 287).

(4) Nutrient losses

Based on literature, the following major sources of nutrient losses from manure treatment, storage and application can be distinguished:

- Uncovered lagoons (emissions of ammonia NH_3 and methane CH_4),
- Solid manure storage and composting (nitrogen loss up to 60 %),
- Superficial application of manure without immediate mixing or covering with soil (ammonia emission, phosphate run-off),
- Manure application outside the growing season of crops (ammonia emission, nitrate leaching, phosphate run-off and leaching),
- Manure application with nutrient loads far in excess of the crop uptake (exceeding Good Agricultural Practice application standards for nitrogen and phosphate). Nutrients that are not used by crops will be lost.

For two large cattle farms that were visited estimations were made of the yearly manure nutrient production and the manure nutrient supply (N and P_2O_5) per hectare of agricultural land. Both farms use the liquid fraction from a screw press separator for irrigation of crops on a significant and known area of agricultural land.

The calculations are based on the assumptions that the manure production per cow in China and in the Netherlands is the same (comparable milk production levels), that the manure from large scale modern intensive cattle farms in China has the same nutrient levels as in the Netherlands (comparable diet compositions) and that screw press filters, made in China, have a comparable separation performance for nutrients as screw press filters made in the Netherlands. The results of the calculations are presented in Table 11-3. Note that possible nitrogen losses from long-term lagoon storage of the liquid fraction prior to land application and the possible effect of sedimentation of phosphate are not taken into account.

As a reference, the legal maximum application rates for nitrogen and phosphate on agricultural land in 2015 in the Netherlands[27] are 385 kg N/hectare/year and 100 kg P_2O_5/hectare/year for highly productive grassland (1 hectare = 15 mu). The application rates in the Netherlands are based on nutrient removal by crop uptake, *i.e.* that the aim is to achieve a balance between nutrient input and output of the land.

[27] Mestbeleid 2014 – 2017 Tabellen:
http://www.rvo.nl/onderwerpen/agrarisch-ondernemen/mest-en-grond/mest/gebruiksnormen/dierlijke-mest
http://www.rvo.nl/sites/default/files/2015/09/Acrobat-document.pdf
http://www.rvo.nl/sites/default/files/2015/01/05d3bbc6-ff47-4804-b0fe-c8fd848fc2bb.pdf

Table 11-3 Calculated fertilization rates for nitrogen and phosphate in kilograms per hectare of agricultural land, fertilized with liquid fraction from cattle slurry separation, and maximum application rates in the Netherlands for grassland.

	Nitrogen application rate (kg N / hectare / year)	Phosphate application rate (kg P_2O_5 / hectare / year)
Farm No. A	3.730	959
Farm No. B	2.638	897
Max. application rate in the Netherlands	385 (for grassland)	100 (for grassland)

N.B.: Possible nitrogen losses from long-term lagoon storage of the liquid fraction prior to land application and the possible effect of sedimentation of phosphate are not taken into account.

Although the nutrient application rates on the two farms in Table 11-3 must be regarded as rough estimates, it is clear that the nitrogen and phosphate application rates, applied on the two Chinese farms are 7 to 10 times higher than the *maximum* application rates in the Netherlands (only valid for highly productive grassland without grazing). Phosphate content (P_2O_5) is calculated as 2.29 times the analysed phosphorus (P) content in fertilizers/manure. If more than one crop per year is grown (which is the case for most farms that we visited), higher application rates can be justified. But even then, application rates are still much higher than the maximum rates that are used in the Netherlands.

In the Netherlands, the maximum application rates for corn are 185 kg/ha/year and 75 kg/ha/year, for N and P_2O_5, respectively. For winter wheat, the maximum rates for N and P_2O_5 are 245 kg/ha/year and 75 kg/ha/year, respectively.

Nitrogen losses from and phosphate sedimentation in the lagoons requires further study.

(5) Anaerobic Digestion

Controlled anaerobic digestion, i.e. the production of biogas from liquid manure, is an interesting option for the production of renewable energy at large dairy farms. Biogas is mainly composed of 55-60 % combustible methane (CH_4) and 30-35 % carbon dioxide (CO_2). By application of anaerobic digestion technology, the uncontrolled emission of methane from slurry storage can be reduced. The emission of methane is unwanted, because it is a potent greenhouse gas (25 times more powerful than CO_2). After removal of the toxic and corrosive component hydrogen sulphide (H_2S) that may be present in biogas at an acutely lethal concentration of 3.000 ppm (0.3 %) and more, biogas can either be used as fuel in a Combined Heat and Power (CHP) unit for the production of electricity (*e.g.* at location 7), or used as such for household purposes like cooking and heating (*e.g.* at location 6).

Lagoons for the storage of untreated cattle slurry or liquid fraction from slurry separation can be transformed into a biogas reactor by covering the lagoon with a gas-tight foil and collection of the biogas that is produced under the cover. Even if the produced biogas is not used, flaring of the biogas in a biogas burner is preferred over release of biogas to the atmosphere in order to prevent the significant greenhouse gas emission of methane.

The liquid fraction from separation of fresh manure with a screw press filter has a relatively high biogas potential, only slightly less than the biogas potential of fresh slurry. The required residence time in a biogas reactor is shorter (e.g. 3 weeks) than for unseparated slurry (e.g. 7 weeks), since the larger organic particles that require a longer residence time are already removed by the separator. Therefore the volume of the biogas reactor can be proportionally smaller. Furthermore, mixing and pumping of the liquid fraction requires less energy because of the lower viscosity of the liquid. When the waste heat of a CHP-unit is used for heating (e.g. the biogas reactor, offices, milking parlour), the use of coal for heating can be reduced.

The economic viability of the anaerobic digestion of only cattle slurry should be established case by case, since anaerobic digestion of only cattle slurry in the Netherlands is not economically feasible, despite government subsidies for renewable energy. The investment costs and manure disposal costs in the Netherlands are the main obstacles. In China, the cost calculations could lead to a different outcome.

Digestate, the effluent from anaerobic digestion of cattle manure, has the same nutrient levels as undigested, fresh manure, although the rapid availability of some nutrients (primarily nitrogen) for plant growth is somewhat increased by the decomposition of organic matter and related increase in pH-value (from pH 7.5 to pH 8.0 - 8.5). Organic carbon (C) is transformed into methane CH_4 and carbon dioxide CO_2, the main constituents of biogas.

11.5.1.5 Conclusions and recommendations

Generally speaking, cattle slurry and anaerobic digester effluent are valuable fertilizers that can be employed in feed and food production in an environmentally and economically justified way.

However, when large numbers of animals are concentrated in a relatively small area (as is the case in parts of China and The Netherlands), the available area of agricultural land may be insufficient for manure application. In that case, to avoid over-fertilization, the surplus manure should be transported to a region where it can be used responsibly as fertilizer on agricultural land.

In our opinion, further research and extension should be aimed at increasing the manure nutrient efficiency. This means that losses to the environment (e.g. to groundwater tables, surface water, air) are minimized. The nitrogen losses from lagoons and phosphate sedimentation in the lagoons requires further study. Besides reducing losses to the environment, increasing manure nutrient efficiency also means that expenses for chemical fertilizer purchase can be reduced. Unavoidable nutrient losses following manure application (approx. 40-80 % of total N, depending on manure type and application technology) can be compensated with chemical nitrogen fertilizer.

We suggest to establish recommended and maximum nutrient application rates for nitrogen and phosphate from animal manure in China. These application rates may be differentiated with regard to crop and soil types and different climate zones in China. In the meantime, provisional application standards could be established for nitrogen and phosphate fertilization per mu (from animal manure and from chemical fertilizers). In this way all stakeholders (farmers, extension, officials etc.) can gain experience with using application standards. Finally, experiences in the Netherlands and other countries show that a combination of legislation and enforcement is essential to achieve the set goals and to prevent dumping of large manure volumes on small areas of agricultural land.

Chemical analyses of the nutrient (N and P) contents of cattle slurry, anaerobic digester effluent, solid and liquid fractions and other manure products, are often lacking at the moment. However, these values are essential for the calculation of accurate crop specific fertilization rates, or the calculation of how much manure can be adequately utilized per mu (15 mu = 1 hectare).

The development and dissemination of knowledge on the nutrient levels in organic fertilizers in relation to the nutritional needs of crops is highly desirable. This includes the interpretation by farm managers of the results of chemical analysis of organic fertilizers and soils.

Figure 11-8 Taking samples of composted manure for laboratory analyses of the nutrient content, indispensable for the calculation of 'how much manure can be adequately utilized per mu' (15 mu = 1 hectare). Datong Sifang Dairy Farm, Datong, Shanxi.

Finally, we recommend to formulate farm specific 'Manure Nutrient Management Plans' for new large-scale livestock farms, in order to prevent the occurrence of manure surpluses at large-scale dairy farms without enough arable land. One of the main elements in such a plan is a calculation on how much manure and nutrients are produced per year, how this manure is treated or utilized on the farm or what happens with it when it is transported to other farms or companies. Plans for application of manure to crops must include a calculation of manure and nutrients application rates. This means that an inventory has to be made of regional opportunities for manure nutrient utilization in cattle feed and food crop production, prior to establishing a new livestock farm.

Annex 11-1 Field visits WP 5 Beijing, Shanxi and Hebei provinces, China 3-5 June and 16-24 September 2015

Date & Name of company	**Number of milking / total cows /hectares**	**Floor- and manure system**	**Manure treatment and storage**	**Remarks/questions**
June 3 Huachen dairy farm	160/350 cows, no farm land	Inside scraped concrete with outside yard	700 tons/year of dry solids from outside runs is sold to other farms, 300 tons/year of wet solids from inside to biogas installation. No storage. Own transport. Manure is sold for 30 Yuan per ton.	Liquid (urine) is evaporated/ infiltrated. Inadequate manure system.
June 3 / September 17 Zhongdi Farm (SDDDC)	2.200/4.400 cows on 20 hectares, 67 hectares own farm land	Inside scraped concrete with outside yard	Scraped manure is flushed permanently through channel with liquid fraction from separator. Solid fraction is extensively composted and sold to adjacent arable farms. Liquid fraction is stored in 3 covered foil basins (storage capacity 3 x 10.000 tons) and one uncovered earthen basin (capacity ?) and used for irrigation of corn/wheat on 67 hectares belonging to Zhongdi farm. Split manure applications in July (after winter wheat) and November/December (after corn).	Manure separators: inclined screen separator and screw press filter. Well-designed manure system.
June 4 Baoding Shuangfeng dairy farm	460/1.000 cows, no farm land	Inside scraped concrete with outside yard	Scraped manure is flushed periodically through channels with added water. Solid fraction from separator is dried/composted and stored in shed. Solid fraction is used for bedding and 3.000 tons/year are sold for 35 Yuan/ton. Liquid fraction is stored in 3 open concrete basins (estimated capacity 3 x 400 tons) and used for irrigation by other farms (5.000 tons/year ?!).	Screw press manure separator. Well-designed manure system. Limited storage capacity for liquid fraction.
June 4 Yiren cooperative dairy farm	540/1.200 cows, 27 farmers, no farmland	Unpaved yards with brick or concrete floored shelters	Solid farm yard manure is periodically gathered for free by manure sellers.	No designed manure system. Liquid (urine) is evaporated/infiltrated.
June 5 Lvhe Dairy (Government farm)	1.600 cows, no farm land, fish pond	Inside scraped concrete with outside yard	Scraped manure is flushed with water through channels to mixing pit before separator. Solid fraction from separator is stored. Liquid fraction is stored permanently in open foil lagoons.	Sand as bedding material and sand catchers in manure channels. Screw press manure separator. No customers for solid fraction because of lack of nearby farm land and sand in solid fraction.

June 5 Beijing Yingherui Environment Co. Ltd.	Multiple tank CSTR/UASB biogas plant without land, owned by local community	Solid farm yard manure 20 tons/day, 50 m^3 of biogas per ton manure. Input diluted with liquid fraction digestate to 10 % dry matter.	Supply of solid farm yard manure and disposal of digestate for use on farmland is commissioned by local community who sells the desulphurized biogas to nearby residents.	Robust biogas installation with very long manure residence time. Economic efficiency is difficult to calculate because of hidden costs. Reactors heated with coal in winter.
September 19 Saibei Modern Farm (Zhangjiakou Farm, Xiandai Farm) Northern part of Hebei Province, elevation 1.000 meters.	Four standard farms with 10.000 cattle each.	Inside scraped concrete with outside yard	Scraped manure is pumped into tank trucks and transported to anaerobic digester. Digestate is separated by 3 screw press filters and one roller press. Solid fraction is used for bedding. The remaining solid fraction and liquid fraction are transported and applied to agricultural land by a separate company.	Screw press manure separators. Well designed manure system. Biogas is used in CHP for electricity generation. Waste heat is flared by heat exchangers.
September 21 Datong Sifang Farm, Datong, Shanxi Province	Location 1: 700/1.200 cows Location 2: 2.200/6.000 cows	Inside scraped concrete with outside yard	Location 1: Scraped manure is used on adjacent agricultural land. No on-farm storage capacity. Location 2: Scraped manure is flushed through channels with liquid fraction from separators. Solid fraction is intensively composted in greenhouse (with intermittent turning) and further dried in the open air to 80 % DM. Solid fraction is used for bedding and the remaining solid fraction is sold to farmers for 40-50 RMB/ton. Liquid fraction is stored in an uncovered lagoon with waterproof bottom (masonry stones) and used for irrigation on 87 hectares of agricultural land (adjacent greenhouses and arable farms).	Screw press manure separators. Well designed manure system. Turning equipment for tunnel composting. In dry season, further drying of compost on concrete floor outside.

15 mu = 1 hectare = 10.000 m^2

11.5.2 Spreadsheet for manure separation

Calculation tool for manure separation, download link: http://www.sdddc.org/en/download/detail-155.aspx

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