Trop Anim Health Prod (2014) 46:669–673
DOI 10.1007/s11250-014-0550-4

REGULAR ARTICLES

Production level, feed conversion efficiency, and nitrogen use efficiency of dairy production systems in China

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Accepted: 29 January 2014 / Published online: 8 February 2014

Abstract A study was conducted in China to evaluate the feed conversion efficiency, nitrogen use efficiency, and the amount of human-edible grains fed under different dairy systems. Three dairy systems were defined and studied: (i) smallholder subsistence farms (SH), (ii) peri-urban farms (PR), and iii) cooperative farms (CO). The PR system had the highest milk yield, better feed conversion efficiency, better nitrogen use efficiency, and used lower proportion of grains in the diet. Within a system, different farms had wide variations in feed conversion efficiency and nitrogen use efficiency, suggesting the need to improve management practices within the system. Among the three systems, SH and CO systems require the most improvements in the management practices.

Keywords Dairy production system · Feed conversion efficiency · Milk yield

Introduction

The cost of concentrate feed is more than 50 % of the total cost of milk production, and there is a 10-% shortage in food supply in China (Chen 2012). China's growing grain imports could impact the world's grains prices, and further increase in cost of grains could adversely impact food security in other parts of the world.

The milk production in China is projected at 50 million tons in 2015 (MOA 2012). The aim of the first phase of the program launched by the Chinese Agriculture Ministry is to increase animal productivity through breed improvement and increase in feed conversion efficiency (FCE). In an FAO symposium, several authors (FAO 2013) highlighted the importance of characterizing dairy production systems with a focus on FCE.

This study was conducted to investigate the diet composition and FCE in different dairy production systems and to characterize the systems for FCE and economic parameters. This information leads to defining the approaches, appropriate for different production systems, that increase FCE and alleviate productivity-decreasing constraints.

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Material and methods

Farm investigation

This study was conducted in 2012. Field surveys were the primary method for obtaining information from dairy farms. Twenty-three farms, spread all over China, were selected on the basis of differences in management systems and animal numbers. Three dairy farm systems were defined in this study: (i) smallholder subsistence farms (SH): <10 cows per farm and the farm owned by one person or one family; (ii) peri-urban farms (PR): >100 cows herd per farm, with good management practices (i.e., has full-time nutritionist, veterinarian, good working system, and years of experience); and (iii) cooperative farms (CO): usually >100 cows per farm but the cows in the farm owned by several different persons and kept collectively in a farm. These cooperative farms are owned by different persons but are managed by management companies. Sometimes these farms suffer from management-related problems because of different ideas and strategies of the owners to address the same issue and inefficient working system of the management companies.

The data collected were from the field investigations and included type of animals, herd (animals per farm), number of lactating cows, milk yields (lactating cow and herd basis), dry matter intake (DMI; lactating cow and herd basis), and composition of dairy ration. Data on feed price were also collected. Milk and feed data for calculations is on 1-year basis. These data were obtained from the statistic of the dairy farm.

Samples of dairy rations were collected once per month throughout the investigation, and the data were presented as the average value of the whole year. The samples were analyzed for dry matter (DM), crude protein (CP), Ca (AOAC 1990), P (Combs and Satter 1992), and neutral detergent fiber (NDF) (Van Soest et al. 1991).

From the above information, the following parameters were calculated:

(a) FCE=kilogram milk production/kilogram DMI, where both milk production and DMI are the average values for the lactating cows based on one lactation. For determination of the FCE for herd, total milk production in 1 year was divided by the number of cows in the herd, and DMI was the total feed fed to the herd in 1 year divided by the number of cows in the herd.
(b) Economic parameter=kilogram milk production/US$ worth of feed.
(c) Nitrogen (N) use efficiency (UE)=[(kilogram milk yield×3.2 %)/(kilogram DMI×CP%)]×100, where both milk yield and DMI represent the average values for the lactating cows for one lactation. The average CP content of milk was taken as 3.2 %.
(d) Milk produced per unit of human-edible grains in diets= kilogram milk yield/kilogram human-edible grains, where milk yield represents the average value for the lactating cows, and human-edible grains represent the amount of cereals and soybean in the concentrate; both these parameters being for one lactation.

Statistical analysis

Data were statistically analyzed by using GLM procedure of SAS (SAS Institute 2000). Duncan's multiple range tests were used to examine the significance of difference between means. Probability values of $P<0.05$ were used to define statistically significant results, with statistical trends being defined at $P<0.10$.

Results

Status of dairy farms and diet compositions

Information of ten peri-urban farms, seven smallholder farms, and six cooperative farms were collected. The breed in most of the farms was Chinese Holstein; however, some large farms also kept some Chinese Holstein crossbred by Jersey. The number of farms keeping these crossbred dairy cows was small, and the number of crossbred dairy cows was less than 10 per farm. The Holstein and Holstein-Jersey crossbred cows under field conditions are equally treated, while allocating feeds and the management conditions are also similar. Total cows and lactating cows kept by farms of different systems are shown in Table 1, and the average number of herd and lactating cows were much higher in PR compared to CO and SH systems.

The constituents of the concentrates used in the farms in China either under field conditions or in the reported studies were similar, consisting of ground corn grain, soybean meal, cottonseed meal, wheat bran, and barley; and the main roughages were alfalfa, grass hay, and corn silage. As shown in Table 2, the concentrate levels in diets were 53.9, 49.4, and 44.4 % for PR, CO, and SH system, respectively. Also, the dietary CP was highest in PR system, with no difference between the other two systems. Concentrate proportion in dairy ration was highest in the PR system, while it was lowest in SH system, with middle levels for CO system. Grain was one of the most used feedstuffs in the diet in the field investigation. Oil seed meals/cakes used were higher in PR and SH compared with that in CO system; however, the differences were not statistically significant. Grains tended to be used more in SH system compared with the other dairy systems ($P=0.10$).

Production parameters

Comparison results of milk yield and DMI information of different dairy farm systems are shown in Table 2. The PR system had the highest DMI of lactating cows, while SH system the lowest DMI. On herd basis, the DMI of PR system was the highest. Milk yield of PR system was 17.4 or 36.2 % higher than that of CO or SH system. On herd basis, PR system had the highest milk yield.

The milk yield per unit of human-edible grains was higher in PR system than the other two systems (Table 2). The farmers in SH system used the highest proportion of human-edible grains, but the milk yield per unit of human-edible grains in this system was the lowest among all the dairy systems.

Table 1 Information of different systems of dairy farms investigated

Item	Feeding systems		
	PR	CO	SH
Number of farms investigated	10	6	7
Herd size (head)	990±140[a]	643±96	3±1
Lactating cows (head)	590±76	345±79	2±0.3
Facility	Advanced	Outdated	Outdated
Management	Good	Mid-level	Poor

PR peri-urban farms, *CO* cooperative farms, *SH* smallholder subsistence farms

[a] Mean±SEM

Economic parameter

The economic parameter "milk produced per unit cost of the diet" for different systems of dairy farms and from the Chinese published literature is shown in Table 2. Under field conditions, no statistic significance was found among PR, CO, and SH systems, although the value in SH system was numerically higher.

FCE and NUE

Most lactating dairy cows in China were operating with an FCE of less than 1.40. The highest FCE for herd was found in PR system (1.45), while the lowest was in CO system (0.53). The FCE on herd basis was lower than that of lactating cows. As shown in Table 2, FCE for lactating cows was significantly higher in PR system than that in the other two systems. The FCE for herd was also highest in PR system.

The NUE was higher in PR system (0.273) than that in CO (0.244) and SH systems (0.229), with no statistical difference between CO and SH systems. When calculated on the herd basis, as expected, these values were lower.

Discussion

Composition of diets as concentrate, roughage, and minerals

The types of feed ingredients used in the formulation of dairy rations were more diverse in PR and CO dairy farms compared with SH dairy farms, leading to the balanced nutrients in

Table 2 Comparison of feed composition, production parameters, and economic parameters between different systems of dairy farms

Item	Feeding systems			SEM	*P*
	PR	CO	SH		
Concentrate (%DM)	53.9	49.4	44.4	3.04	0.28
Roughage (%DM)	43.0	46.7	54.0	3.32	0.23
Premix (%DM)	3.41a	3.22a	1.03b	0.37	<0.01
Grains (%DM)	27.1	29.2	35.1	2.32	0.10
Meals (%DM)	11.4	9.90	8.42	1.20	0.88
CP (%DM)	16.0a	15.2ab	14.2b	0.21	<0.01
Ca (%DM)	0.90a	0.85a	0.56b	0.05	<0.01
P (%DM)	0.57a	0.47ab	0.37b	0.03	<0.01
NDF (%DM)	36.3b	37.1b	43.5a	1.41	<0.01
ME intake[a] (MCal/d)	4.83ab	7.20a	2.17b	1.05	0.04
MP intake[a] (g/d)	59.4ab	177.0a	−20.4b	46.9	0.05
Milk per human-edible grains	5.20a	4.11ab	3.17b	0.44	0.02
Lactation cow basis					
Dry matter intake (kg)	19.7a	19.1a	16.1b	0.66	0.01
Milk yield (kg)	27.0a	22.3b	17.2c	1.30	<0.01
Feed conversion efficiency	1.36a	1.17b	1.06b	0.03	<0.01
Nitrogen use efficiency	0.27a	0.24b	0.23b	0.004	<0.01
Herd basis					
Dry matter intake (kg)	16.8a	11.6b	13.4ab	1.40	0.07
Milk yield (kg)	16.4	14.3	14.5	0.63	0.08
Feed conversion efficiency	1.01a	0.79b	0.90ab	0.051	0.05
Nitrogen use efficiency	0.20	0.17	0.21	0.010	0.06
Economic parameter[b]	2.67	2.51	2.73	0.066	<0.01

PR peri-urban farms, *CO* cooperative farm, *SH* smallholder subsistence farms

a, b, c Within a row means without common letters differ ($P<0.05$)

[a] Predicted by NRC (2001) model based on measured DMI and individual feedstuffs in MOA (2004) guidelines

[b] Economic parameter: kilogram milk production/US$ worth of feed

PR and CO systems. The farmer in PR system used the highest proportion of concentrate in the diet, with the lowest in SH system. Overall, the percentages of concentrate, roughage, and grains in dairy rations were similar among three different systems. A higher level of grains in SH system indicate that if the scale of dairy farms with SH system increases, more human-edible resources might be used in livestock production.

FCE and NUE

In a study from India, the FCE of low- (<8 kg/day), medium- (8–12 kg/day), and high-yielding (>12 kg/day) cows were 0.4, 0.6, 0.8, but increased to 0.7, 0.8, 1.0, respectively, after feeding balanced rations (Garg et al. 2012). Most dairy herds in the European Union currently are operating with an FCE of less than 1.20 kg of energy corrected milk (ECM) per kilogram of DMI (Colman et al. 2011). The assumed FCE in the NRC system (NRC 2001) for cows producing 40 kg milk/day is approximately 1.49 (Colman et al. 2011). Recent measures on typical dairy farms in the USA by D. E. Beever (Richard Keenan and Company, Borris, Co. Carlow, Ireland, personal communication) indicated only a marginally lower value, with most below 1.30 kg of ECM per kilogram of DMI. These observations suggest that the FCE of PR system in China are higher than those in India, but are still lower than those in the USA and European Union. However, the FCE of CO and SH systems in China are similar to those in India.

When estimated by CPM Dairy software, all the dairy rations used in the three systems were adequate in energy; however, the diets of SH system were limited in metabolizable protein content. The challenge for PR system farms is to further improve the FCE while decrease the running cost since milk production per US$ worth of feed was not higher than in other systems. For CO system, the challenge appears to be improvement, in a unified manner, of the overall management of the dairy farms. The SH system dairy farms have a number of constraints, for example, use of outdated technology and equipment and poor environmental and hygienic conditions in the farm that compromise animal comforts and adversely affect productivity. Furthermore, use of high proportion of human-edible grains, poor quality of roughage, and low milk quality mainly as a result of poor hygienic conditions, which are characteristic of SH system, decrease profitability. Based on the FCE of the three systems and the analysis above, it may be surmised that for improving the dairy industry in China and to make its resource efficient, it is important to improve the FCE in all systems and to improve the management in both the CO and SH systems through technology transfer and providing knowledge and information on good management practices to the owners of these farms. In addition, the owners of CO farms have to ensure that their management acts in a unified manner and makes decisions on sound scientific basis.

Another prime goal for all dairy farms is the optimization of feed-N use efficiency, i.e., to maximize milk production per unit of N consumed. Conversion of feed-N into milk was higher in PR system compared with that in CO and SH systems, suggesting that dietary N is utilized better for milk protein synthesis in PR system with less N loss in urine and feces. The risk of N pollution was lowest in PR system compared with other systems. The FCE of PR system in this study was quite close to other studies (Wang et al. 2008, NUE=0.27; Wang et al. 2010a, NUE=0.34).

The average proportion of dietary N secreted into milk increased from 0.15 to 0.24, 0.18 to 0.26, and 0.24 to 0.29 in low-, medium-, and high-yielding cows, respectively, on feeding a nutritional balanced diet (Garg et al. 2012). The dairy systems in the present study have similar NUE values comparable with those of the Indian dairy cows when they are fed nutritionally balanced diets. Powell et al. (2013) showed that the NUE for Indian dairy cows was 0.11, even lower than that in SH system in this study. However, in another study by Powell et al. (2008), the NUE values were 0.22 and 0.25 for two commercial dairy farms in China, while the NUE was 0.194 for China calculated by the Life Cycle Assessment model. The NUE also increased from 0.26 to 0.30 when the cows were fed a Met and Lys supplemented diet (Wang et al. 2010b), indicating that balancing of diet for amino acids can also increase the NUE. However, the FCE and nutritional level was not always positively correlated. In a study by Wang et al. (2007), the FCE decreased from 0.33 to 0.27 when the MP level increased from 8.3 to 10.4 % of DM.

A wide range of FCE (herd basis) in the farms in PR (0.85 to 1.45), CO (0.59 to 0.90), and SH (0.83 to 1.10) systems suggests that within a system, substantial improvements can be made in the efficiency of resource use and in the profitability by having a better understanding of the management practices and putting in place the interventions to overcome the constraints. These variations in FCE within a system could possibly be reduced by managing the diets properly. However, much more efforts are required in proper herd management.

Milk performance and economics

Overall, large-scale farms, most in PR system, are using good balanced feeds. However, small farm owners, most in the SH system, feed the dairy cow based on their experiences and are not in a position to hire specialists that could assist them in preparing balanced rations.

Although the farms in SH system are using the highest ratio of grains, the FCE and milk yield per unit of human-edible grains in this system are the lowest. The concentration of grains used in the diet of CO system was similar to that in PR system. However, the FCE was highest in PR system compared with that in CO system, which may be ascribed to the feeding of nutritionally balanced diet and better management in PR system. This means that productivity of dairy cows can be improved without increasing the concentration of grains in the diet. The way forward is to feed the animals a nutritionally balanced diet, including proper and balanced supply of AA in the diet and to improve the management.

The PR dairy farms are using many feed additives that may contribute much to the feed cost. This may be the reason for lower economic parameter value for the PR system despite having higher FCE. It is also worth noting that FCE and NUE were lowest in SH system, but milk produced per US$ worth of feed was highest.

The purchase price for milk produced in SH and CO systems (US$0.39 to US$0.47) was lower compared with that in PR system (US$0.50 to US$0.56/kg), on average US$0.14/kg lower (Liu and Li 2012). This lower milk price in SH and CO systems was due to the lower nutritional composition of milk produced in these farms. Taking the lactating cows in this study, a 0.1-gain in FCE will deliver an extra 2.0, 1.9, and 1.6 kg of milk/day for PR, CO, and SH systems, respectively. That would be worth US$1.06, US$0.89, and US$0.69/day on the gross margins at a milk price of US$0.53, US$0.47, and US$0.43/kg for PR, CO, and SH systems, respectively.

Conclusions

The PR dairy farms in China had the higher milk yield, better FCE, and better NUE. The farmers in this system used lower level of grains in the diet. Taking into account the higher purchase price of milk and less use of grains in the PR dairy farms, the profitability and ecological and food security benefits are much higher in the PR dairy farms.

Acknowledgments This study was supported by the earmarked fund from China Agriculture Research System (CARS-37), the national Spark Program project (2013GA7000023), and the Zhejiang Province Public Technology Applied Research Projects (2013C32069).

Conflict of interest The authors declare that they have no conflict of interest.

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