Relationships between management factors in dairy production systems and mental health of farm managers in Japan

H. Kato,^{1*} H. Ono,² M. Sato,³ M. Noguchi,⁴ and K. Kobayashi¹

¹Research Faculty of Agriculture, Hokkaido University, Sapporo 060-8589, Japan

²College of Bioresource Sciences, Nihon University, Fujisawa 252-0880, Japan

³Faculty of Health Sciences, Hokkaido University, Sapporo 060-0812, Japan

⁴Japanese Red Cross College of Nursing, Tokyo 150-0012, Japan

ABSTRACT

To facilitate sustainable dairy farming, it is essential to assess and support the mental health of dairy farm workers, which is affected more than that of workers in other industries, as indicated by the relatively few studies to date. In addition, the limited investigations on mental health in dairy workers minimize the opportunities to suggest practical approaches of improvement of their mental health. Therefore, further data acquisition and analysis is required. In the present study, we undertook quantitative surveys on 17 management factors and administered a mental health questionnaire to 81 dairy farm managers (80 male, 1 female) in Hokkaido, northern Japan. The management factors were categorized into 3 groups: production input, production output, and facility indicator; mental health was evaluated based on the Center for Epidemiologic Studies Depression Scale (CES-D). Principal component analysis assigned the factors into 2 groups: intensiveness factors of dairy production systems (PC1: livestock care cost, fat- and protein-corrected milk, stocking density, medical consultation fee per unit time per animal unit, non-family wages, fertilizer and pesticide expenses, and net agricultural income ratio) and basic dairy management factors (PC2: net agricultural income ratio, quantity of concentrate feed, and milk quality variable). The depression symptoms of dairy farm managers were not significantly associated with PC1 and milking methods; however, they were significantly negatively associated with PC2, which integrated 3 management factors, including factors related to finances, feeding, and milk quality. According to the findings of the present study, the efforts needed for stable economic farm management, adequate feed supply, and milk quality maintenance may increase the depression levels of dairy farm

managers and negatively affect their mental health. These findings could be the basis for future studies on the relationship between the mental health of farm managers and sustainable dairy farm management and production.

Key words: dairy farmers, management factors, mental health, simultaneous nature of the demands

INTRODUCTION

In recent years, the Japanese dairy farming industry has experienced several changes. The signing of the Comprehensive and Progressive Agreement for Trans-Pacific Partnership by 11 countries, including Japan, on December 30, 2018, which excludes tariffs on agricultural products, has increased the import of agricultural products. Moreover, over the years, Japan's food self-sufficiency rate has been on a downward trend, with approximately 37% based on calorie and 66% based on production value in 2018, compared with 43% and 74%, respectively, in 1995 (MAFF, 2018b).

The aging of farm workers is also a severe problem influencing agriculture in Japan; the average age of individuals mainly engaged in farming was 67.8 years (MAFF, 2020a). The World Health Organization defines old age as persons older than 65 years. According to this definition, the percentage of elderly people engaged in agriculture is extremely high compared with other industries (MHLW, 2019).

Food import and export have increased considerably at an international level; however, the number of farm workers showed a 16% decrease globally between 2000 and 2019 (FAO, 2020). Similarly, the population of people mainly engaged in farming in Japan has decreased from approximately 3.4 million in 1995 to approximately 2.2 million in 2018 (data from MAFF, 2018a). The northernmost prefecture, Hokkaido, is the main food production region in Japan, with a 206% food self-sufficiency rate on a production value basis in 2017 (MAFF, 2018b). Dairy farming is a common ac-

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*Corresponding author: hkato@cen.agr.hokudai.ac.jp

tivity in Hokkaido, accounting for approximately 54.4% of the total milk production in Japan (MAFF, 2018c). However, the number of dairy farms in Hokkaido has decreased in recent years, with only 20 new dairy farms replacing every 200 farms that close each year (Hokkaido Prefecture, 2020).

According to the Japan Policy Council (2014), approximately 78% of the municipalities in Hokkaido would experience depopulation from 2010 to 2040. The depopulation of rural areas has negative effects on education, medical services, health and welfare systems, and other social services. The physical and mental health levels in rural areas are lower than those in urban areas in Australia and the United States (Dixon and Welch, 2000; Hartley, 2004; Smith et al., 2008), and similar observations have been made in Japan (Nishi et al., 2007; Kondo, 2019).

Particularly, the mental health level of dairy farmers is lower than that of workers in other industries (Wallis and Dollard, 2008). Contributing factors to the poor mental health of dairy farmers include financial issues, irregular weather conditions owing to climate change, anxiety about the future of the farm, market price of farm products and livestock, tax, medical treatment fees, and lack of family time (Momose et al., 2008; Kearney et al., 2014; Daghigh Yazd et al., 2019). Kanamori and Kondo (2020) reported that suicide rates were higher in areas with active livestock production in Japan; in addition, a stronger correlation was found between livestock production and suicide among men than among women; however, the reasons for the trends are yet to be clarified.

To facilitate sustainable dairy farming, it is critical to assess and support the mental health of dairy farm workers. According to Hansen and Østerås (2019), correlations exist among farmer welfare, farmer stress, and animal welfare. King et al. (2021) investigated relationships between the mental health of dairy farmers and milk production and udder health, in addition to indicators of farm animal welfare. Anxiety and depression were greater among farmers on farms that produced milk with lesser milk protein percentages. Research on the relationship between farm animal welfare and farmer welfare has been initiated, and some findings are beginning to emerge in the farm animal welfare research field. Dairy farms with different types of facilities are evaluated using indexes of physical strain and mental stress as part of occupational health and safety assessments in research on public health (Karttunen et al., 2016).

However, the limited investigations on mental health issues in dairy workers reduce the opportunities for recommendation of practical approaches to address the

challenge. Therefore, the aim of this study was to examine the relationship between management factors and mental health among 81 dairy farm managers (80 male, 1 female) on selected dairy farms in Hokkaido, using quantitative surveys. Management factors include the number of livestock bred, the quantity of feed provided, farming materials invested, and milk production and revenue. An understanding of the major management factors that negatively affect the mental health of dairy farmers would facilitate formulation of policies and practical approaches to supporting dairy farm workers, and facilitate sustainable farming activities.

MATERIALS AND METHODS

Ethical Considerations

This study was approved by the Ethics Committee of the Research Faculty of Agriculture, Hokkaido University, Sapporo, Japan, on October 4, 2018 (additional approval on November 8, 2018), to protect the rights of the participants in the study. The results of the study are accessible to farmers who provided written consent during the study.

Selection of Study Site and Farms

Despite the increased promotion of intensification, mechanization, and scaling of dairy management to improve productivity in Hokkaido, approximately 80% of the farms breeding dairy cattle older than 2 years old are family-run businesses with fewer than 80 cattle, and this is the mainstream management style (data from MAFF, 2019b,c). On average, there are 2.4 family farm workers and 73.7 cattle per farm in Hokkaido (Kato et al., 2018).

The study was conducted in town A and town B in Hokkaido. The key industry of town A is agriculture, where approximately 65% of farms engage in stockbreeding (dairy farming) and 35% in field farming, and the town is known as a field farm and dairy farm mixture area. The key industry of town B is also agriculture, but most farms engage in stockbreeding (dairy farming), and the town is known as a grassland dairy farming area. The research team collaborated with the Japan Agricultural Cooperative (JA; Chiyoda ward, Tokyo, Japan), which is an agricultural organization, in data-collection activities, based on the principle of mutual cooperation.

A total of 100 farms in town A and 135 farms in town B belong to JA. We selected 42 farms in town A and 39 farms in town B for survey and data collection. Details of the selected farms are shown in Table 1.

Table 1. The number of dairy farms, cows, milk production value ratio, and dairy management details

Item	Unit	Japan	Hokkaido	Town A	Town B
Dairy farms	Farm	15,700.0 ¹	6,140.0 ¹	100.0 ²	189.0 ²
Cows	Herd/farm	84.6 ¹	128.8 ¹	187.9 ²	118.9 ²
Ratio of milk production value in agricultural production value	%	8.3 ¹	30.4 ¹	48.3 ¹	74.4 ¹
Number of study farms	Farm	—	—	42	39
Milking type					
Pipeline	Farm	—	—	20	29
Milking parlor or automatic milking system	Farm	—	—	22	10
Barn type					
Stanchion barn	Farm	—	—	18	24
Loose barn	Farm	—	—	24	15

¹MAFF Hokkaido (2020).²MAFF (2020b).

Research Items: Defining the Management Factors of Dairy Production Systems

Management factors are the essential elements influencing a dairy production system, such as the number of livestock bred, the quantity of feed provided, farming materials invested, milk production and revenue, and so on. In this study, management analysis was conducted using a mainly financial table, which was divided into 3 categories: input, output, and facility, with a total of 18 key management-related variables in the categories **V01** to **V18**. These items were used to examine the management factors of the dairy farmers. Table 2 shows an itemization of managerial factors in this study.

Management Factors in Dairy Production Systems Index 1: Input Indicators

Production-Based Indicators. The production-based indicators were stocking density [animal units (AU)/ha, V03] and the amount of concentrate feed provided (kg/milking cow per year, V04). The stocking density was obtained by dividing the management area (ha, V01) by the AU (V02). The management area was the total grassland, pastureland, grass crop fields, leased land, and other crop fields, excluding residential areas, mountains, forests, and leasehold land provided to a tenant. The AU was determined based on the AU coefficient for livestock bred on farms (Kato et al., 2018). The amount of concentrated feed provided (kg/milking cow per year) was the amount of concentrated feed provided to a milking cow per year. The variables in this study were converted into units per milking cow, AU, and management area for clarity.

Nonfamily Wage Indicators. In dairy production systems, the level of dependency on external labor is a variable that has significant influence on both economic

efficiency and the workload of family farm workers. The variable includes nonfamily wages (yen/AU, V05). For farming households for which nonfamily wages could not be separated from the total labor cost (11 households), the average value of the ratio of nonfamily wages to the total labor cost for each milking type was calculated and corrected to obtain the value of nonfamily wages. The proportions of nonfamily wages within the total labor cost were 17, 71, and 58%, representing pipeline, parlor, and automatic milking system (AMS), respectively. The value of 100 Japanese yen (US\$0.92) in March 12, 2020, was used for wage calculation.

Environmental Load Indicators. The demand for environmentally conscious production systems is considerable. Taking this into account, we included fertilizer and pesticide expenses per unit area (yen/ha, V06) and electricity, water, gas, and fuel expenses per unit area (yen/ha, V07) as variables in this study. These expenses were considered to represent environmental loads, which are sufficient to evaluate relative impact in our statistical analysis.

Livestock Disease Indicators. In dairy production systems, livestock disease significantly influences both economic efficiency and milk production. Parameters such as livestock care cost (yen/AU, V08), number of medical visits per livestock unit (times/AU, V09), and livestock medical fees (yen/AU, V10) were set as livestock disease indicators in this study. Livestock care costs included sanitation expenses, artificial insemination fees, deposit fees, litter fees, and hoof cutting fees. Livestock medical fees, including both medical and technical fees, are expressed as medical consultation fee per unit time per AU (MFTA, yen/times per AU, V11). The criterion for being visited or not visited by a veterinarian varies among farm managers; therefore, it may not be an ideal factor for expressing the current situation on the farm. However, livestock medical fees and number of livestock medical visits were consid-

Table 2. Descriptive statistics of the study farms by 2 different milking systems

Variable number	Variable description ¹	Unit	All farms (n = 81)			Pipeline milking (n = 49)			Milking parlor or AMS ² (n = 32)			P-value ³
			Mean	SD	CV	Mean	SD		Mean	SD		
V01	Farmland	ha	64.8	50.0	0.77	53.2	26.5		82.6	69.4	0.028*	
V02	Cows by AU	AU	145.7	119.3	0.82	92.8	68.8		226.5	135.0	0.000***	
V03 ⁴	Stocking density	AU/ha	2.7	2.6	0.96	2.1	2.1		3.7	3.1	0.008***	
V04 ⁴	Concentrated feed	kg/milking cow per year	2,851.6	1,301.5	0.46	2,636.5	1,156.4		3,180.8	1,454.6	0.065	NS
V05 ⁴	Nonfamily wages	1,000 yen/AU	46.2	84.0	1.82	22.5	67.5		80.9	94.2	0.004***	
V06 ⁴	Fertilizer and pesticide expenses	1,000 yen/ha	88.8	75.1	0.85	74.2	73.2		111.3	73.5	0.029*	
V07	Electricity, water, gas, and fuel expenses	1,000 yen/ha	148.0	160.2	1.08	111.6	139.7		203.7	175.3	0.011*	
V08 ⁴	Livestock care cost	1,000 yen/AU	66.0	55.2	0.84	54.3	47.9		83.8	61.4	0.018*	
V09	Number of livestock medical visits	Times/AU	1.9	1.1	0.61	1.8	1.2		2.0	1.1	0.552	NS
V10	Livestock medical fees	1,000 yen/AU	21.7	13.9	0.64	25.1	16.0		16.7	7.5	0.002***	
V11 ⁴	MFTA	Yen/times per AU	172.0	160.9	0.94	224.3	156.7		91.9	133.7	0.000***	
V12 ⁴	FPCM	kg/milking cow per year	8,922.3	1,607.5	0.18	8,443.3	1,576.6		9,655.7	1,379.1	0.001***	
V13	Agricultural income	1,000 yen/AU	1,323.7	681.4	0.51	1,216.5	746.6		1,487.7	538.0	0.080	NS
V14	Agricultural expenses	1,000 yen/AU	1,007.5	569.1	0.56	901.9	611.7		1,169.3	460.0	0.038*	
V15	Net agricultural income	1,000 yen/AU	316.1	169.0	0.53	314.6	175.5		318.4	161.1	0.921	NS
V16 ⁴	Net agricultural income ratio	%	25.1	8.4	0.33	27.2	8.3		22.1	7.6	0.006***	
V17 ⁴	LS	—	2.4	0.5	0.19	2.5	0.5		2.4	0.4	0.209	NS
V18 ⁵	CES-D total score	—	12.6	8.9	0.70	12.6	10.2		12.5	6.5	0.960	NS

¹AU = animal units; MFTA = medical consultation fee per unit time per AU; FPCM = fat- and protein-corrected milk; LS = milk quality variable; CES-D = Center for Epidemiologic Studies Depression Scale.

²AMS = automatic milking system.

³NS = not significant.

⁴Principal component analysis variables.

⁵Binomial logistics regression analysis variable.

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

ered adequate to indicate the comprehensive livestock health, and in turn, the major farm animal welfare indicators (Kato et al., 2018).

Management Factors in Dairy Production Systems Index 2: Output Indicators

Production Indicators: Fat- and Protein-Corrected Milk. The major management goal of dairy production system is the sustainable production of fresh milk. Therefore, milk output was used as the productivity index in this study. Milk production was calculated based on the value of fat- and protein-corrected milk (FPCM, V12; IDF, 2010). The FPCM is a system that corrects the variability of fat and protein content of produced milk to standardized ratios of 4.0% and 3.3%, respectively, and is used to compare milk with varying fat and protein contents. The FPCM is calculated using the following equation:

$$\text{FPCM (kg/yr)} = \text{Production} \times (0.1226 \times \text{Fat\%} + 0.0776 \times \text{True protein\%} + 0.2534),$$

where production is in kilograms per year.

Economic Indicators. We also examined the economic sustainability of the dairy production systems. The indicator used for this was collected from the farm accounting table, known as KUMIKAN, in Japan. Japan's KUMIKAN is a network of microeconomic data based on bookkeeping principles similar to the Farm Accountancy Data Network used in the EU.

Data captured in KUMIKAN are limited to the content of transactions between farms and JA, and does not keep track of transactions that do not go through JA. The depreciation costs of equipment and facilities are also not included; however, they are useful in analyzing the economy. Agricultural income (yen/AU, V13), agricultural expenses (yen/AU, V14), net agricultural income (yen/AU, V15), and net agricultural income ratio (% , V16) were calculated using KUMIKAN data. Net agricultural income was obtained by subtracting agricultural expenses from agricultural income. The net agricultural income ratio was the ratio of net agricultural income to agricultural income, which indicates economic efficiency. In this study, the net agricultural income ratio (% , V16) was adopted as the productivity index variable:

$$\begin{aligned} \text{Net agricultural income (1,000 yen)} &= \\ \text{Agricultural income} - \text{Agricultural expenses;} \end{aligned}$$

$$\text{Net agricultural income ratio(\%)} = \frac{\text{Net agricultural income}}{\text{Agricultural income}} \times 100.$$

Milk Quality Indicators. The quality of milk produced has a considerable effect on the profitability of dairy production systems. Japanese dairy manufacturers set the market price of milk based on the somatic cell count of fresh milk, nonfat milk solids ratio, and butterfat (Snow Brand Seed Co., 2010). In this study, the average somatic cell count (V17) was used as the milk quality variable (LS). Somatic cell count is a general term for the concentration of white blood cells and shed epithelial cells in milk, and is characteristically high in mastitis-infected cattle. Herd and population somatic cell counts are related to the inflammatory process in individual cows. They reflect the udder health status of the herd and the quality of the raw milk in the herd and the population (Schukken et al., 2003). The LS is obtained by taking the logarithm of the somatic cell count per 1 mL of fresh milk produced by milking cows and is graded from 0, as the optimal milk quality grade, to 9 (Aihara, 2013). In Japan, the management goal is to maintain the number of herds with grade 5 or higher (SCC of 283,000–565,000 cells/mL) at less than 8% in all herds.

Management Factors in Dairy Production Systems Index 3: Facility Indicators

The milking type and feeding method of each farm were used as the facility variables. Each variable was converted into a dummy variable. The milking types were pipeline and milking parlor or AMS and were assigned scores of 0 and 1, respectively. Tiestall and freestall or free-barn feeding methods were assigned scores of 0 and 1, respectively. The feeding facilities of 83.7% of pipeline farms were tiestalls, and those of 96.7% of milking parlor or AMS farms were freestall or free barns. In this study, milking type was used as the facility index of the farms.

Data from 2018 were used to examine the management factors of dairy farms. Data provided by JA were used as key items associated with business overview and economic efficiency. Information on farm livestock diseases was based on livestock medical records provided by the National Agricultural Insurance Association. Variables associated with milk quality were based on data from the dairy herd improvement program by the Hokkaido Dairy Milk Recording and Testing Association.

Farmers' Mental Health (Index of Farmer Welfare): Depressive Symptoms

Mental health is increasingly a source of concern as an occupational and widespread issue in Japan. According to the Ministry of Health, Labor, and Welfare (MHLW,

2009), the economic losses attributed to mental health issues amount to approximately 2.7 trillion yen in 2009. Particularly, depression, as one of the major diseases, tends to be lifelong, and it is used extensively in medical services as a measure of workers' mental health. Depression affects mental and physical health and, as the most common mental illness, is an important public health problem (Liu et al., 2020). In the present study, the mental health status of farm workers was evaluated based on depression systems using the Center for Epidemiologic Studies Depression Scale (**CES-D**, V18), a 20-item assessment that is commonly used to screen for depression. The CES-D has been translated into more than 30 languages, and its reliability and validity confirmed in the Japanese version (Shima et al., 1985). The CES-D has also been applied in mental health research among farmers (Yazd et al., 2019).

In the CES-D, each question item asks how often respondents have experienced the symptoms within the last week, and responses are based on a scale ranging from 0 to 3: for instance, 0 = rarely or none of the time and 3 = most or all the time (5–7 d). All responses are added to obtain a total score; the potential range of the total score is 0 to 60. A cut-off point of 15 or 16 is commonly used to identify those with depressive or those with non-depressive symptoms on the CES-D scale. In the present study, participants with a total score of 0 to 15 were categorized as non-depressive, and those with total scores of 16 to 60 were considered as having depressive symptoms.

For the analyses, each cut-off value was converted into a dummy variable; depression and non-depression were assigned scores of 1 and 0, respectively. This was a cross-sectional study. The survey on the mental health of 81 farm managers (80 male, 1 female) was conducted via questionnaires from December 2018 to February 2019, and the CES-D score of the farm manager was used to determine the level of depression.

Research Framework and Statistical Analysis

A basic statistical analysis of the variables was conducted, and a *t*-test was used to compare the mean values of 2 populations with 2 different milking methods: pipeline as conventional milking type, and parlor and AMS as semi-automatic or automatic milking type (Table 2). Parlor and AMS milking methods have less quantitative workload than pipeline milking. Mean values were considered significant at $P < 0.05$.

Subsequently, Pearson correlation analysis was performed to investigate the relationships between the variables. Correlation was considered significant for 2-tailed at the levels of $P < 0.05$ or $P < 0.01$. Variables

with a Pearson correlation coefficient and coefficient of variation of less than 0.8 and more than 0.1, respectively, were applied in a principal component analysis (**PCA**; Pearson, 1901). Principal component analysis is a technique that creates new synthetic variables from multiple data variables, to facilitate interpretation of data. In this study, the principal factor method of PCA was used to aggregate and interpret management factors.

The PCA calculated the principal components, which are new variables constructed as linear combinations of the initial variables. The standardized factor loading should be greater than 0.5 for interpretability criteria (Hair et al., 2009). Therefore, in this study, the variables with factor loadings greater than 0.5 or less than -0.5 in each principal component were considered essential interpretability criteria. Simultaneously, each farm's principal component score was calculated for component eigenvalues greater than 1.0.

Associations between the variables and the mental health of farm managers were assessed using binary logistic regression analysis (Cox, 1958), with the CES-D cut-off value as the dependent variable and the principal component score and facility index variable as the explanatory variables. All data analyses were performed using SPSS Statistics version 27 (IBM Corp.).

RESULTS AND DISCUSSION

Descriptive Statistics

Preliminary statistics for the variables used in the study are presented in Table 2. We found no significant difference in the number of livestock medical visits; however, the MFTA was significantly higher in the pipeline system than in parlor or AMS systems. In the present study, data on the number of livestock medical visits and medical fees were based solely on the consultation record of veterinarians, without consideration of on-farm treatments. Although livestock care cost was included in this study as a livestock disease indicator, it will also be necessary to evaluate farm animal welfare based on physiological indices and housing facility conditions in the future. Regarding the economic efficiency of the 2 systems, we observed no significant differences between the agricultural income ($P = 0.080$) and net agricultural income ($P = 0.921$) generated in both systems. However, parlor and AMS milking had significantly higher ($P = 0.038$) agricultural expenses compared with the pipeline system, whereas the pipeline system had a significantly higher net agricultural income ratio. This is an indication that the pipeline system is a more economically efficient system despite

its low total agricultural income. No significant difference was detected between the total CES-D ($P = 0.960$) scores of farm managers in the 2 systems.

Correlation Matrix

The results of the correlation analysis of the variables are shown in Table 3. The AU ($r = 0.625$; $P < 0.01$), quantity of concentrate feed provided ($r = 0.307$; $P < 0.01$), nonfamily wages ($r = 0.541$; $P < 0.01$), fertilizer and pesticide expenses ($r = 0.514$; $P < 0.01$), electricity, water, gas, and fuel expenses ($r = 0.843$; $P < 0.01$), livestock care cost ($r = 0.658$; $P < 0.01$), FPCM ($r = 0.635$; $P < 0.01$), and number of livestock medical visits ($r = 0.333$; $P < 0.01$) were significantly positively correlated with stocking density. The higher the stocking density, the higher the quantity of inputs for production. A strong positive correlation was detected between agricultural income ($r = 0.519$; $P < 0.01$), agricultural expenses ($r = 0.601$; $P < 0.01$), and stocking density; and a weak positive correlation ($r = 0.262$; $P < 0.05$) was found between net agricultural income and stocking density. The net agricultural income ratio was significantly negatively correlated ($r = -0.449$; $P < 0.01$) with stocking density, indicating that highly intensive dairy management systems are not always economically efficient. Livestock medical fees (1,000 yen/AU; $r = -0.378$; $P < 0.01$), MFTA (yen/times per AU; $r = -0.760$; $P < 0.01$), and LS ($r = -0.290$; $P < 0.01$) were significantly negatively correlated with stocking density.

The replacement time for cows is usually short under intensive management of high-producing dairy cows (Ohgi and Shiga, 2001). This is due to increases in occurrence of illness (Ohgi and Shiga, 2001) and somatic cell counts of fresh milk (Sasano, 1998) as the parity increases. Ohgi et al. (2001) reported that farms with high-producing dairy cows were more willing to cull cows with mastitis and reproductive disorders than farms with low-producing dairy cows. Dairy farming is privately controlled, and, therefore, farmers maintain profitability and milk quality by culling sick animals to cut down on livestock medical expenses. This may not be considerate for the welfare of the farm animal. Such a practice in the livestock industry that does not take into account farm animal welfare could affect farm sustainability in the long term. We found no significant correlation between the total CES-D score (V18) and the variables. In a previous study, no association was found between milk yield, somatic linear score, and farmer depression (King et al., 2021). The scales used to assess mental health in this study were different from those used in the earlier study; however, similar results were obtained for the single-correlation relationship,

with no correlation between milk yield, LS, and CES-D depression symptoms.

Integration of Management Factors in Dairy Production Systems Index: PCA

Variables with Pearson correlation coefficients and coefficients of variation less than 0.8 and more than 0.1, respectively, were used for PCA. A total of 10 representative variables were selected initially. Electricity, water, gas, and fuel expenses per farmland had a strong correlation ($r = 0.842$; $P < 0.01$) with stocking density, and, therefore, they were combined to form one variable. Nine variables were used for PCA (Table 4).

The results of PCA showed that the cumulative contribution rate of the variables in principal components 1 and 2 (**PC1** and **PC2**) was 56.2%. Livestock care cost, FPCM, stocking density, MFTA, nonfamily wages, fertilizer and pesticide expenses, and net agricultural income ratio were clustered in PC1, with a contribution rate of 38.3%. Variables with factor loadings >0.7 , including livestock care cost, FPCM, and stocking density, were extracted as positive loadings. High factor loadings indicate a high correlation between the assessment items and each factor. Management systems with high FPCM and stocking density are usually highly intensive. Therefore, variables clustered in PC1 were classified as “intensiveness factors.”

Net agricultural income ratio, quantity of concentrate feed, and LS were clustered at PC2, with a contribution rate of 17.9%. Management factors in PC2 were basic; one factor is related to feeding, one is related to finances in general, and the last is related to milk quality. Therefore, PC2 was classified as “basic dairy management factors.” Considering the factor loadings in PC2, it was found that a high net agricultural income ratio, which indicates a positive loading rate, leads to stable economic farm management. High concentrate feed quantity, indicating a positive loading rate, implies adequate feed supply to cows. Low LS had a negative loading rate and indicated high milk quality. Thus, PC2 could also be expressed as “well-managed farm systems.” Table 2 shows no statistical mean difference in the quantity of concentrate feed and LS, between the different milking systems, or in other words, between different farm sizes. These 2 variables are considered as management factors dependent more on the farm managers’ decisions than the milking system or farm scale. Therefore, PC2 consists of dominant management factors influenced by farm managers’ decisions.

The factor loadings for net agricultural income ratio in PC1 were negative, which indicates that the farms with low net agricultural income ratio are highly intensive farms. The net agricultural income ratio of PC2

Table 3. Pearson correlation matrix on all dairy management factor variables (n = 81)

Variable number and definition ¹	Unit	V01	V02	V03	V04	V05	V06	V07	V08	V09	V10	V11	V12	V13	V14	V15	V16	V17	V18
V01: Farmland	ha	1																	
V02: Cows by AU	AU	0.507**	1																
V03: Stocking density	AU/ha	-0.243*	0.625**	1															
V04: Concentrated feed	kg/milking cow per year	-0.174	0.170	0.307**	1														
V05: Nonfamily wages	1,000 yen/AU	0.015	0.513**	0.541**	0.178	1													
V06: Fertilizer and pesticide expenses	1,000 yen/ha	-0.236*	0.227*	0.514**	0.064	0.531**	1												
V07: Electricity, water, gas and fuel expenses	1,000 yen/ha	-0.332**	0.456**	0.843**	0.325**	0.621**	0.703**	1											
V08: Livestock care cost	1,000 yen/AU	-0.261*	0.374**	0.658**	0.217	0.487**	0.622**	0.705**	1										
V09: Number of livestock medical visits	Times/AU	-0.175	0.132	0.333**	-0.004	0.300**	0.527**	0.447**	0.471**	1									
V10: Livestock medical fees	1,000 yen/AU	0.191	-0.186	-0.378**	-0.001	-0.252*	-0.413**	-0.425**	-0.273*	0.271*	1								
V11: MFTA	Yen/times per AU	-0.080	-0.743**	-0.760**	-0.094	-0.623**	-0.648**	-0.757**	-0.627**	-0.468**	0.507**	1							
V12: FPCM	kg/milking cow per year	-0.125	0.444**	0.635**	0.480**	0.504**	0.427**	0.662**	0.571**	0.332**	-0.151	-0.525**	1						
V13: Agricultural income	1,000 yen/AU	-0.446**	0.081	0.519**	0.289**	0.555**	0.780**	0.784**	0.659**	0.475**	-0.388**	-0.537**	0.641**	1					
V14: Agricultural expenses	1,000 yen/AU	-0.399**	0.192	0.601**	0.283*	0.598**	0.784**	0.824**	0.711**	0.529**	-0.327**	-0.605**	0.678**	0.956**	1				
V15: Net agricultural income	1,000 yen/AU	-0.486**	-0.152	0.262*	0.334**	0.282*	0.573**	0.499**	0.432**	0.167	-0.461**	-0.262*	0.401**	0.757**	0.593**	1			
V16: Net agricultural income ratio	%	0.032	-0.395**	-0.449**	0.011	-0.448**	-0.422**	-0.505**	-0.420**	-0.496**	-0.008	0.513**	-0.330**	-0.363**	-0.578**	0.242*	1		
V17: LS	—	0.060	-0.234*	-0.290**	-0.209	-0.215	-0.107	-0.191	-0.191	0.078	0.277*	0.210	-0.263*	-0.124	-0.103	0.185	0.065	1	
V18: CES-D total score	—	0.058	0.030	-0.049	0.027	-0.045	0.013	-0.036	0.047	-0.030	0.110	0.017	-0.014	0.013	0.011	0.025	0.009	0.050	1

¹AU = animal units; MFTA = medical consultation fee per unit time per AU; FPCM = fat- and protein-corrected milk; LS = milk quality variable; CES-D = Center for Epidemiologic Studies Depression Scale. Correlation is significant for 2-tailed at * $P < 0.05$ or ** $P < 0.01$.

Table 4. Principal component (PC) factor loadings for 9 dairy management factor variables¹

Item	Unit	PC1	PC2
Variable number and definition			
V08: Livestock care cost	Yen/AU	0.788*	−0.002
V12: FPCM	kg/milking cow per year	0.715*	0.321
V03: Stocking density	AU/ha	0.715*	0.341
V11: MFTA	Yen/times per AU	−0.681*	0.313
V05: Nonfamily wages	Yen/AU	0.633*	−0.221
V06: Fertilizer and pesticide expenses	Yen/ha	0.610*	−0.480
V16: Net agricultural income ratio	%	−0.533*	0.528*
V04: Concentrated feed	kg/milking cow per year	0.413	0.633*
V17: LS	—	−0.337	−0.579*
Eigenvalue	—	3.449	1.611
Contribution rate	%	38.3	17.9
Cumulative contribution rate	%	38.3	56.2

¹AU = animal unit; FPCM = fat- and protein-corrected milk; MFTA = medical consultation fee per unit time per AU; LS = milk quality variable.

*Loadings with absolute value greater than ± 0.5 .

had a positive factor loading. Farms with higher net agricultural income ratio are associated with feeding and milk quality, which indicates the latent meaning of the PC2 as “well-managed farm systems.” The agricultural income ratio influenced PC1 and PC2, indicating that economic efficiency was a key factor in assessing management conditions.

Relationship Between Management Factors and Depression Symptoms of Farm Managers: Binomial Logistic Regression Analysis

A binary logistic regression analysis was performed using the cut-off value of CES-D as the dependent variable, and PC1, PC2, and facility index variable as independent variables (Table 5). A *P*-value of 0.445 in the Hosmer–Lemeshow goodness of fit test indicated that the model was well-fitted. In addition, the discriminant contingency table correctly predicted 78.5% of the subjects. The highest odds ratio in PC2 (2.237), compared with those in PC1 and milking type (0.870 and 1.909, respectively) indicated it had the greatest

influence on depressive symptoms. However, the depressive symptoms of farm managers was not significantly associated with intensiveness factors (PC1; *P* = 0.684) and milking type (*P* = 0.307). In contrast, PC2 score was significantly related (*P* = 0.018) to depressive symptoms, which indicated that farm managers with depressive symptoms had superior dairy management factors, which were evaluated based on net agricultural income ratio, concentrated feed provided, and linear score of somatic cell count. An increase in PC2 score was associated with depression conditions; and, therefore, we hypothesized that better dairy management had positive effects on mental health. However, the results were inconsistent with our expectations.

Psychological and physical subjective symptoms, including anxiety and depression symptoms, are considered as psychological reactions that are part of the acute stress response and are reported as theoretical models of work stress (Hurrell and McLaney, 1988; Araki and Kawakami, 1993). In this section, we discuss the stressors in dairy management that bring about depression symptoms. The targets of this study are the

Table 5. Binomial logistic regression analysis of 3 factors relating to depressive symptoms

Variable ¹	B ²	SE of B	Odds ratio	95% CI		<i>P</i> -value ³	
				Lower	Upper		
PC1 score (intensiveness factors)	0.139	0.304	0.870	0.479	1.580	0.648	NS
PC2 score (basic dairy management factors/ well-managed farm systems)	0.805	0.341	2.237	1.148	4.362	0.018*	
Milking system type ⁴	0.647	0.634	1.909	0.552	6.608	0.307	NS

¹PC = principal component.

²B = coefficient of the model equation.

³NS = not significant.

⁴Reference category is 0 as pipeline milking system.

**P* < 0.05.

farm managers. Mental health problems are observed mainly in managers involved in their company, due to financial problems and the demands of running the business continuously (Ishino et al., 2009; Sano and Tanaka, 2012). Managers could be under more financial stress than employees, because they have to ensure sustained financial management. We discuss how each dairy management factor, such as agricultural income ratio, concentrated feed provided, and LS, is a stress factor and how they are related in dairy management. Dairy farmers are under pressure to maintain high milk quality, to avoid fines in the event of supplying fresh milk with high somatic cell count (Kurihara and Shimoura, 2008). They have to pay great attention to feeding approaches, including nutrient balance and feeding methods, because, for example, roughage ratio in animal feed influences milk components (Akuzawa and Ishibashi, 2007; Moorby et al., 2009). Individual daily hygiene management of dairy cows requires that farmers expend considerable mental effort to keep the udders clean and healthy, and in facility management, which could greatly influence milk quality (Japan Dairy Council, 2004). Kawai et al. (2009) reported that milk hygiene, which affects somatic cell count, is determined by the performance of dairy cows during the dry period, timing of implementation of post-dipping, degree of overmilking, dip type, use of milking gloves, and method of injection of ointment during mastitis treatment. Overall, milking activity should be performed under hygienic conditions and with care. The factors are interrelated with each other, and they influence each other; it is difficult to improve each of them in isolation. In our PCA, PC2 indicates the integrated influence of the 3 factors. Therefore, the important point in this study is “the simultaneous nature of the demands.” This is probably because the maintenance of proper financial status, feeding environment for cows, and milk quality simultaneously lead to high psychological stress levels for farm managers. Therefore, it can be inferred that the application of appropriate techniques to run well-managed farm systems requires considerable effort and sacrifices from farm workers and managers, which can cause and increase stress. In other words, the simultaneous nature of the demands cannot be measured simply in the form of good business conditions or low LS. Furthermore, the present research is based on an observational study, so that it cannot make conclusions regarding causation. In future, it will be necessary to examine the causality of the present results in a research framework that includes variables such as psychological stress and actual physical and mental exertion.

However, we suggest that a practical approach for improving mental health on farm is “taking measures of sustaining the simultaneous nature of the demands

in addition to stable economic farm management, adequate and rapid feed supply, and milk quality maintenance.” The results from this study could be helpful for supporting dairy farm management and future research.

Limitations of the Study and Future Work

This study was conducted in only 2 towns in Hokkaido and is not necessarily a true representation of the status in the entire country. Furthermore, questionnaires were administered only to farm managers, without considering other farm workers and gender differences. Over the years, there has been an increase in the participation of women in different sectors and industries of the economy, including agriculture. According to MAFF (2019a), approximately half of the population involved in agriculture are women. In addition, women account for 24.0% of all new farm workers, and the ratio of the female population among all core persons mainly engaged in farming is highest among those in their fifties, indicating that women play an important role in agricultural management. Moreover, in addition to wage-earning jobs, women in Japan often have family responsibilities, such as domestic chores and childcare (Tsuru, 2007). Future studies should examine the mental health of female dairy farm workers.

CONCLUSIONS

This study examined the relationship between management factors and the mental health of dairy farm managers. The findings of this study showed that depression symptoms of dairy farmers were significantly negatively associated with the application of basic dairy management factors, including stable economic farm management, adequate and rapid feed supply, and milk quality maintenance. The limitations inherent in these factors could increase the depression levels of dairy farm managers and negatively affect their mental health, suggesting that sustaining the simultaneous nature of the demands requires overworking. Measures should be put in place to reduce physical and psychological stress among dairy farm workers for improved mental health. Improved mental health of the farmer has a positive effect on farm animal welfare. Unfortunately, in Japan, the term “farm animal welfare” is not well known, and farmers and consumers are unaware of it. Improving mental health of farmers could lead to positive changes in farmers’ behavior toward livestock. This could improve the dairy production system in Japan and simultaneously address farm animal welfare, therefore enabling implementation of a more sustainable production system. Improving the mental health of agricultural employees should be emphasized for

sustainable agriculture. There is a need to formulate policies and establish social systems that consider the physical and psychological health of dairy farm workers.

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ORCIDS

- H. Kato <https://orcid.org/0000-0002-4251-2552>
H. Ono <https://orcid.org/0000-0001-6075-8620>
M. Sato <https://orcid.org/0000-0002-5715-0566>
M. Noguchi <https://orcid.org/0000-0002-5360-8218>
K. Kobayashi <https://orcid.org/0000-0002-4063-2964>