Introduction of Smart Diary Farming and an Enclosed Diary House with Low Profile Cross Ventilation System

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ABSTRACT

Information and Communication Technology (ICT) has been introduced into Japanese dairy farming positively in order to improve productivity and to solve the Japanese issues those are lack of workers, prevention of heat load, control of epidemic and so on. Dairy farming is the most advancing field of ICT use in Japanese agriculture. Ministry of Agriculture, Forestry and Fisheries, Japan has been also promoting “smart agriculture” which is new type agriculture to realize labor saving, high precision farming and high-quality production using ICT, “Internet of Things” (IoT) and robots. Japanese dairy farming has been already introducing many those technologies beginning with a milking robot, etc. In this paper, those technologies used in Japanese dairy farming are introduced, which are milking robot, automatic feeder, automatic litter distributor, power assist suit, motion sensor, cloud system and so on. And then the concept of “Smart Dairy Farming” and the developing stage those the author proposes are described. A Japanese enclosed dairy house system with push and pull low profile cross ventilation (LPCV) system which the author developed is mentioned as one kind of ICT dairy farming. This system used ICT has achieved high environmental control and improvement of production. The results of this system indicated increasing milk yield during summer season, preventing diseases, improving reproductive performance and reducing odor dispersion. A demonstration experiment of smart dairy farming based on the above LPCV system under going is introduced.

Keywords: Dairy farming house, ICT, low profile cross ventilation (lpcv), milking robot, motion sensor, smart dairy farming

INTRODUCTION

Row milk production in Japan tends to decrease, number of Japanese dairy farms has been decreasing at about 4 % every year and the 15 000 farms exist in 2019. On the other hands, number of dairy cows is 1 332 000 heads and over the last 2 or 3 years it tends to be increased slightly. That means Japanese dairy farms are growing in size and that herd size are increasing (MAFF, 2019a). In this circumstances, Japanese issues of dairy farming are pointed out as the following. They are farmers shortage, aging workers and long working hours which are common issues in Japanese agriculture, heat stress to cows in summer seasons, prevention of epidemics, increasing feed self-sufficiency and so on. Specially, heat stress is one of the most important issues and the effects of heat stress on dairy cows reduce milk yield, feed intake, increase water intake, respiration rate, body temperature and change metabolic rate, blood hormone concentrations (Armstrong, 1994). In Japan the number of disused or dead dairy cows were 2405 bodies in 2010 even though Hokkaido where is northern district. The situation has been much the same as before for some years ahead. To those issues, information and communication technology (ICT) and automatic machines such as milking robots have been introduced into dairy farming as measures. Dairy farming in Japan is probably advanced production system which introduced those
technologies in Japanese agriculture.

In this paper “Smart Agriculture” we named in Japan, was mentioned and the smart dairy farming was described. The next generation enclosed dairy house adapted ICT was introduced, which author’s research group (smart dairy consortium) developed. Moreover, our initiative was introduced that the smart dairy consortium is making efforts towards demonstration experiment of smart dairy farming under On-farm demonstration trials of smart agriculture.

SMART AGRICULTURE IN DAIRY FARMING

Japanese ministry of agriculture, forestry and fisheries (MAFF) has been also promoting “smart agriculture” which is new type agriculture to realize labor saving, high precision farming and high-quality production using ICT, “Internet of Things” (IoT) and robots (MAFF, 2019b). In dairy farming various ICTs are also proposed and some those have been sold already. For examples, there are milking robots as their representative, automatic feeder, automatic feed pusher, automatic litter distributor, automatic scraper, sensor system to manage an individual animal, cloud and so on. These can be classified roughly three types those who are system of a single animal bio-information and its interpretation such as detection of diseases, estrus and delivery, the second one is automatic equipment such as a robot and the last one is Cloud. The smart dairy consortium proposes an image of “Smart Dairy Farming (SDF)” elements as shown in Fig.1. Essentially it seems to be required an electronical identification of each single animal. This is achieved by RFID (Radio Frequency Identification) in dairy farming. On the other hand, it is necessary to exam the meaning and cost performance in hog raising and poultry raising for identification of each animal. Bauerdick et al. (2019) showed sensor systems in German dairy farming as shown in Fig.2. This is current one example to collect a single animal’s bio-information. Many devices are attached to cow’s body and there are many devices installed in a livestock house. It is desirable to be collected the bio-information with contactless equipment and a few kinds sensors as much as possible.

Figure 1. Element of Smart Dairy Farming (SDF)

![Diagram of Smart Dairy Farming (SDF)](image-url)
Furthermore, the smart dairy consortium proposes SDF level even though to be disputed. It is shown in table 1. It shows the development level of each element basically. Final goal which our group image is that cloud can support decision-making or decide management and control each equipment who is linked up. The system can detect bio-information of a single animal such as diseases, estrus, delivery, weight, body condition score and milking with a few non-contact sensor devices.

According to size of farm, required kind of ICT by family farmer is seem to be different from those by large size farm corporations manage. The smart dairy consortium considers that it is important to make a menu of SDF each farm size and to make sure of the cost.

Table 1. Proposed SDF level

<table>
<thead>
<tr>
<th>Level</th>
<th>Sensing hooked into the Network, individual Bio-Information</th>
<th>Automatic equipment</th>
<th>Decision-making Integrated control Cloud</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Weather factors • Temperature, RH, air speed, gas, bacteria, aerosol</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Electronic identification</td>
<td>Milking Feeding Environment control</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Milking Info.</td>
<td>Bedding</td>
<td>Visualization of collected data, alerting</td>
</tr>
<tr>
<td>4</td>
<td>Estrus Delivery</td>
<td></td>
<td>Equipment control</td>
</tr>
<tr>
<td>5</td>
<td>Disease Weight (from image) BSC</td>
<td></td>
<td>Decision-making for management</td>
</tr>
</tbody>
</table>

A NEXT GENERATION ENCLOSED DAIRY HOUSE SYSTEM

This system was developed in order to comprehensively solve the issues of Japanese dairy farming which are lack of workers, aging or workers, heat stress in summer season, control of epidemic, odor, and so on. Our research group adapted an enclosed housing system with low profile cross ventilation (LPCV) for above. The 80 - milking cow enclosed dairy free-stall house with LPCV was constructed to research the effect at a mega farm in Tochigi prefecture (Fig.3) in 2015. Therefore, this model house was a little bit the over specification. It had 78 fans (outlet fan) to exhaust inside air and 66 fans (inlet
fan) to push outside air into inside house. In a practical manner, number of inlet fans was able to be reduced to 8 fans from the results of our research (Ikeguchi et al. 2015). The width was 24.9 m, the length was 64 m, the ridge height was 7.4 m and the eave height was 4 m. There were 3 row stalls and 2 units of milking robots (GEA Farm Tec, MIone) were installed.

**Heat Stress**

One of the most important issues to be considered is relief of heat stress in Japanese dairy productions as ambient temperature has been rising because of global warming. The counter measures of relieving from heat stress have been watched on and the effective technologies are desired. The effects of heat stress on dairy cows reduce milk yield, feed intake, increase water intake, respiration rate, body temperature and change metabolic rate, blood hormone concentrations (Armstrong, 1994). In Japan the number of disused or dead dairy cows were 2405 bodies in 2010 even though Hokkaido where is northern district. The situation has been much the same as before for some years ahead.

There are several ways to prevent from heat load such as water spraying, factional coating material, air conditioner (heat pump) and so on. Our approach was to remove heat from a cow body by air flow based on heat convection. Because latent heat affects cows more than sensible heat, that is that moisture content in the air affect cows more than air temperature. Therefore, an enclosed building with LPCV was adapted because it makes spatially uniform more than 2 m/s air flow (Fig. 4). Tunnel ventilation has been spread specially in poultry houses and piggeries, but the demerits are to be easily made space distribution of environmental factors and to hardly control local environment. LPCV can overcome those.

![Figure 3. The next generation enclosed dairy house](image)
Control of epidemic

As the building was enclosed, birds and beasts can not invade into the building and this building can prevent pathogen from being brought by them. Also, this prevents blood sucking insects which mediate bovine leukemia invading into the house. And then air cleaner with photocatalyst was installed as to reduce concentration of air born microbe during winter ventilation.

Odor diffusion control

In Japan, the another most important issue id odor problem. There are many complaints of odor from the neighborhood. The location of exhausted air (outlet) is unambiguous because of forced ventilation. Bio-filter was installed at the outlet. The bio-filter can reduce dispersion of odor and aerosol particles in which odor elements and microbes including virous attach. Pruned branch of pear was used as bio-filter as pear is cultivated more popular in this area.

Saving labor & Cloud

Milking is the most labor work and a milking robot can save labor. 2 units of milking robot were installed in this system. Feed push robot and automatic scraper were adapted. Environment control with fans was automatically controlled. The fans were controlled with THI or amended THI which has not only temperature and relative humidity (RH) but also air speed and radiation from the roof. The information of running each machine, environmental factors such as temperature, RH, air flow speed, THI, and milking info. were collected to the cloud and they were visualized.

Renewable Energy

Solar panels were established on the southern roof. Moreover, heat collecting system from row milk was established to make 85 °C hot water as rinse water.

Achievement of the system
The above functions conducted reduced heat load in summer season from June to September. Inside temperature was decreased about 2 °C compared to the open type house which was built in the same farm and had conventional cooling spray and fans. The fig. 5 showed both amended THI of this house and the open house as an example. It was significantly decreased in the next generation enclosed dairy house. As the physical environment in this house was improved and reduced heat load to the cows’ body, number of panting was significantly reduced (Fig. 6). This means that heat stress in this house was smaller than that in open house. The most important milk yield in this house increased significantly rather than that in the open type house. The fig. 7 shows comparation of different between expected milk yield and actual milk yield in this enclosed house to that in the open type house. Because there is individual specificity of milk yield, the different between expected milk yield and actual milk yield was adapted. The other effects of this system on productivity were reduction of number of mating and incidence of mastitis.

In winter ventilation season, the air cleaner with photocatalyst could reduce concentration of airborne bacteria including pathogen of mastitis to about 99 %. And then bio-filter could reduce dispersion of odor to outside to about 50 %.
Based on the next generation enclosed dairy milking house system mentioned above, brushed up smart dairy farming system has been developed by the smart dairy consortium. A demonstration experiment has been conducted under On-farm Demonstration Trials of Smart Agriculture. The overview is seen in Fig.8. Several ICT equipment were added into the next generation enclosed housing system, those were an automatic feeder, an automatic litter distributor, behavior detecting system to detect estrus and disease and cloud to manage.

Challenging technologies developed are early detection of hoof disease from behavior with motion sensor and artificial intelligent (AI) and detection of milk constituent for each cow with near infrared and detection of herd location in the house. Local environment in the house is controlled from the information of herd location. This conducts to saving fans’ electric energy and leads to saving cost. The cloud participates in the control. These are under development and the economic efficiency would be also exposed.

**CONCLUSIONS**

![Figure 7. The different between actual milk yield and expected one](image)

**A DEMONSTRATION EXPERIMENT OF SMART DAIRY FARMING BASED ON A NEXT GENERATION ENCLOSED DAIRY HOUSE SYSTEM**

![Figure 8. Overview of SDF developed](image)
Smart agriculture and Smart dairy farming were described and the effect of the next generation enclosed dairy housing system into which ICT and AI were introduced on productivity was described. And then a demonstration experiment of smart dairy farming was introduced. Though dairy farming is the most advanced field introduced ICT compare to the other agricultural field in Japan, these technologies have not been integrated by cloud and the economic efficiency is not gratifyingly demonstrated. These are future works.

Basically bio-information of a single animal is fundamental information to produce highly and the detecting sensor devices as few as possible and non-contacted devices are desirable. At first it is necessary to identify a single animal electrically.

REFERENCES


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