The Design and Evaluation of a Multi-player Milk Supply Chain Management Game

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Abstract. There are various brands of milk with different "best use before" dates in supermarkets. Each milk package must be sold by this corresponding selling time limit, which is set as two-thirds of the time of its best used before date from production under the so-called one-third rule. If the milk remains unsold when the selling time expires, milk waste occurs. This paper gives a detailed design of a milk supply chain game that simulates the situation and carries out the game experiments. In addition, a questionnaire is completed before and after the experiments to help evaluate the educational effect of the game in increasing awareness of food waste.

Keywords: Milk industry · Dairy farm · Supermarket · Supply chain
Waste

1 Introduction

Many milk-based drinks are currently available in the marketplace and the nutritional benefit that milk provides, such as calcium, is well known. As most Japanese people are said to be deficient in this [1], the recommendation is that they drink milk regularly. However, there is a decreasing trend in its consumption and a large amount of raw milk is reportedly wasted every year. For example, in 2006, as much as 1,000 tons of raw milk was wasted, with an economic value of approximately 76 million yen [2]. The production volume of raw milk decreases in summer and increases in winter because the body condition of a cow is weakened by the summer heat and recovers in winter [3]. In contrast, the demand for milk from consumers increases in summer and decreases in winter.

For milk with a certain "best used by" date, the period corresponding to two-thirds of the best used by date from production is set as the selling duration and a supermarket has to sell the milk within this period under the so-called one-third rule. There are various brands of milk packages with different best used by dates being sold in supermarkets. If some remain unsold when the selling duration is over, the milk is wasted. Thus, at the International Simulation and Gaming Association (ISAGA)

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conference in 2016, we proposed a milk supply chain game that simulates this situation [4]; in this paper, we elaborate on the design of the milk supply chain game including an auction model and consumer agents. Several other papers are available as references for our study, which designs and evaluates a milk supply chain management game. For example, in one study, a pedagogical game mimicking negotiations in a supply chain was proposed [5]; and in another, the role of gaming simulation in policy research was discussed [6]. Our study was conducted based on this literature, namely, our game experiments were conducted with university students focusing on milk waste under two cases: with and without the one-third rule. In addition, a questionnaire survey was conducted both before and after the game experiments to evaluate the educational effects of the game in increasing food waste awareness and, thereby, ultimately decreasing waste.

2 Methodology

2.1 Game Scenario

The game scenario is shown in Fig. 1. The major stakeholders in a milk supply chain include dairy farmers, milk manufacturers, supermarkets, and consumers. Players are assigned to the roles of three milk manufacturers and three supermarkets, and the transactions between the two roles are modeled as an auction. Dairy farmer roles are modeled by a computer agent, which automatically receives orders for purchasing raw milk from manufacturers. Customer behavior is modeled by a logit model. Therefore, the total number of human players is six.

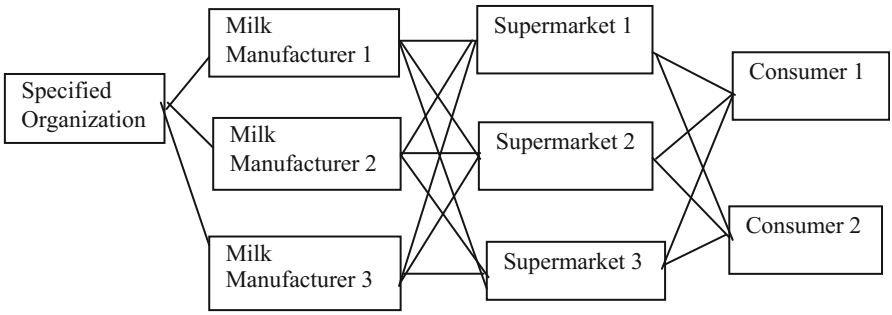

Fig. 1. Game scenario

Once every two days, an auction is conducted between milk manufacturers and supermarkets. The game was played for 13 days fictionally from October 1 to October 13 and the auction was done five times in this game. Each milk manufacturer tries to sell as much milk as possible to as many supermarkets as possible as at high a price as possible, and each supermarket tries to buy milk from as many milk manufacturers as possible as at low a price as possible. The milk manufacturer players make a production

plan so that milk waste does not occur, and the supermarket players need to consider customer behavior. The milk size available is only 1L.

2.2 Player Actions

2.2.1 Milk Manufacturers

Each of the milk manufacturer players can check the total sales account, total waste of milk, amount of raw milk, production plan, total stock of milk, and the result of the last auction at any time.

9 am: Delivery plan

(1) The player creates a delivery plan for milk based on the previous day's auction result.
(2) If the volume of milk sold can be met by the total stock, there is no work for the player here.
(3) If the volume of milk sold exceeds the total stock, the player has to decide how much milk to move to each of the supermarkets 1 to 3.

1 pm: Production plan and the raw milk order (only Tuesday and Friday)

(1) On Tuesday: the amount of milk production will be decided for Friday, next Monday, and next Tuesday.
(2) On Friday: the amount of milk production will be decided for next Wednesday and Thursday.
(3) According to the production plan, raw milk is ordered.
The raw milk ordered on Tuesday is delivered on Thursday, and this milk can be used as of Friday. The raw milk ordered on Friday is delivered on Tuesday, and this milk can be used as of Wednesday (Table 1).

3 pm: Auction time

(1) It is possible to bring to the auction the milk stocked in the warehouse and available by 5 pm of the auction day.
(2) The player offers the volume and selling price of the milk produced every day.

5 pm: Reconsideration of the production plan

The production plan drafted on Tuesday and Friday can be modified the day before (the last decision).

9 pm: Check the sales

Today's sales and the amounts unsold raw milk and milk waste are counted.
To achieve the most points, it is important that the manufacturer player makes good decisions. The points of this player are calculated as follows:

Table 1. Time schedule of the flow of raw milk

Order	Received	Day used
October 1 (Tues)	October 3 (Thu)	October 4 (Fri)
October 4 (Fri)	October 8 (Tue)	October 9 (Weds)

<Plus points>

- The volume of the sales * sale price

<Minus points>

- The purchased amount of raw milk * 10
- The amount of milk that could not be sold * 30% of the price decided by the auction.

2.2.2 Supermarkets

Each of the supermarket players can check the total sales account, total milk waste, stock of milk, and the result of the last auction any time.

9 am: Shelf stacking

The player decides how much milk of each brand with a best sell before date should be moved from the warehouse to the shelf as well as the selling price.

1 pm: Shelf stacking

The player confirms the sales of the milk that were moved to the shelf at 9 am and decides the further amount of the milk to be moved from the warehouse to the shelf and the selling price.

3 pm: Auction time

The player decides on and offers for a purchase amount and a price of the milk produced by the milk manufacturers 1 to 3 on each production date.

5 pm: Shelf stacking and discount

(1) The player moves some milk to the shelf as done at 9 am and 1 pm.
(2) The player may discount the price of milk that has been stacked on the shelf.

9 pm: Confirmation of sales

Today's sales and the amount of the milk wasted are counted.
To gain the most points, it is important for the supermarket player to make good decisions. The points of the supermarket player are calculated as follows:

<Plus points>

- The sales price * (1-discount rate) * the amount of milk sold

<Minus points>

- The amount of milk that cannot be sold * 10
- The purchased amount of milk * the purchase price from the manufacturer.

2.3 Auction Model

The transaction between the manufacturers and the supermarkets is modeled as a double-sided auction. The auction is conducted separately for the milk produced on each day by each milk manufacturer. The manufacturer bids the minimum price and the maximum amount and each supermarket bids the maximum price and the maximum amount for the milk. Then, the bids are aggregated into the supply and demand curves,

and who buys how much of the milk at what price is determined by the intersection point between the curves.

2.4 Logit Model

A logit choice model represents the consumers' preference in which the total utility is determined by the sum of the partial utilities on the price, the discount rate, and the best use before date. The parameter values of the model are estimated through the choice based conjoint analysis. Eighteen university students answered a questionnaire with 20 choice questions created for the analysis and the parameter values were estimated for each respondent. The respondents can be clustered into three groups by applying cluster analysis to the data. Accordingly, three types of consumer agents were created.

In the game, a consumer agent appears following an exponential distribution, and she/he chooses which milk to buy from those on the shelf or decides not to buy any according to the logit choice model with the parameter values corresponding to her/his group. Further, the supermarket he/she goes to is determined by the probability proportional to the mean utility gained in each supermarket by a consumer of the group on the day before.

3 Results

3.1 Milk Manufacture

(1) The difference in milk waste between the cases with and without the one-third rule was analyzed. When the rule was used in the game, the packaged milk waste increased. This is because when the rule was not imposed, the milk manufacturers could sell the milk for 12 days, however, when the rule was imposed in the game, they could sell the milk only for four days. Of note, the number of selling days was significantly fewer.
(2) The data on milk waste on Wednesday, October 2 are shown in Figs. 2, 3, 4 and 5. If the one-third rule is used, the selling time limit of this milk is Sunday, October 6. Since the auction is conducted once every two days, it is only possible to sell this milk on Thursday, October 3. On the other hand, in the case without the rule, this milk can be sold four times during the game period. Thus, when the rule was used, in every round (from 1 to 4) more milk waste was caused for the milk manufacturer. When the one-third rule is used, therefore, a price decision can be made only once, and hence, it is critically important.
(3) However, the difference in the amount of raw milk waste between the cases with and without the one-third rule was not large. This is because the players can review the production plan every day.

3.2 Supermarket

Milk waste occurred between two and four times more when the one-third rule was used during this game. However, when the rule was not used, there was no milk waste

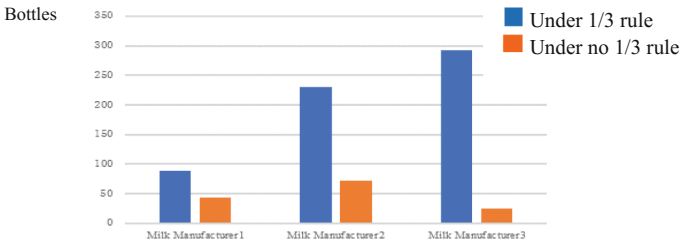

Fig. 2. The waste of milk at the first trial (October 2)

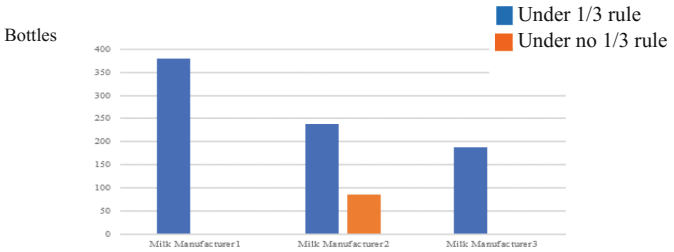

Fig. 3. The waste of milk at the second trial (October 2)

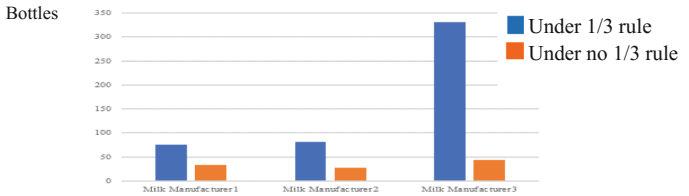

Fig. 4. The waste of milk at the third trial (October 2)

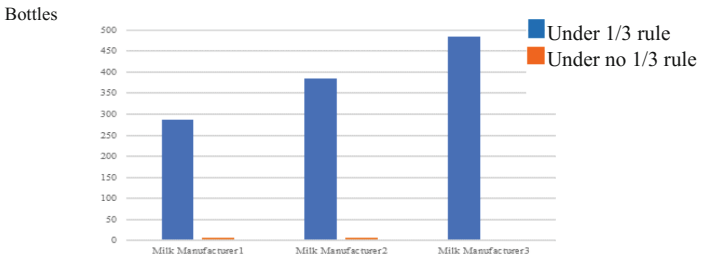

Fig. 5. The waste of milk at the fourth trial (October 2)

or very little. When the rule was imposed, it was clear that the quantity of wasted milk was large. When the rule was used, the sales period was four to seven days. However, when it was not used, the sales period was 11 days. Thus, the sales period without the

rule was longer than with the rule. Therefore, when the one-third rule was imposed, the players could not sell a large amount of stock without wasting milk.

The volume of milk purchased, the volume of milk sold, unsold milk, and waste in the fourth trial is shown in Tables 2, 3 and 4. When the one-third rule is not used, the players can sell a large amount of milk and decrease the amount of wasted milk. Because of this situation, the supermarket players can choose milk with the best sell by date he/she wants to buy from the manufacturer. The supermarket can sell the milk for a longer time and the decision-making period is also longer. Thus, the players are able to consider the consumer's demand as well. When playing without the one-third rule, the supermarket players are able to sell more milk efficiently with less waste than in the alternative case.

Table 2. Milk manufacturer 1 (milk purchased, sales volume, unsold milk, and waste)

	With one-third rule	Without one-third rule
Volume of milk purchased	1986	1360
Sales volume	1046	1238
Unsold milk	863	122
Milk waste	77	0

Table 3. Milk manufacturer 2 (milk purchased, sales volume, unsold milk, and waste)

	With one-third rule	Without one-third rule
Volume of milk purchased	2280	1380
Sales volume	1292	1330
Unsold milk	400	50
Milk waste	588	0

Table 4. Milk manufacturer 3 (milk purchased, sales volume, unsold milk, and waste)

	With one-third rule	Without one-third rule
Volume of milk purchased	2279	1604
Sales volume	1149	1489
Unsold milk	538	115
Milk waste	592	0

3.3 Change in Customer Behavior

Before and after the game, we conducted a survey questionnaire on consciousness regarding food waste. Before the game, we asked the game players, for example, "Do you know the one-third rule?" Only 20% of the players knew the rule (this meant that the majority, 80% did not). Therefore, it was important for these players to learn about the rule. In the survey after the game, we asked, "Have you ever heard news about food waste in Japan?" Of the players, 70% had heard such news, however, only 25%

indicated a consciousness of food waste. In addition, we asked, if "the best use before date of the food has passed, do you still eat the food?" About 60% of the players indicated that they would not eat such food. Although there were many players who knew about the problem of food waste, they did not know the details around the problem.

After the game, we asked, "Do you think about the problem of food waste?" In this survey, 53% of the players who answered stated that we all should think about the problem. However, in the survey before the game, only 30% of the players answered this way. Thus, there was a 23% increase in consciousness regarding food waste after the game. Furthermore, before the game, the ratio of players who checked the refrigerator before going shopping was less than 50%; however, after the game, this increased to 87%. More than 90% of the players answered that they will pay more attention to food waste from now.

4 Study Limitations and Future Considerations

In terms of study limitations, research indicates that a student's ability to apply knowledge is important in solving an internal pricing problem in a supply chain and that such knowledge could affect the results. In addition, the findings should be reconfirmed by using new data to assess the reliability of the results [7]. Thus, it is also important for us to confirm the results with other data and carefully evaluate the effectiveness of the game for the reduction of food waste.

Future study considerations are as follows:

(1) This game tests only 13 days, so we need to lengthen the period and check for milk waste.
(2) Here, the difference in milk waste between the cases with and without the one-third rule was analyzed. Thus, we should try another system, for example, a half rule.
(3) As the players here were university students, we should try to use this game with milk manufacture workers, supermarket workers, and others.
(4) In a supermarket, there are many brands of milk with different sell before dates are being supplied. Therefore, we should incorporate more items into the game.
(5) It remains to be answered whether our game is effective as an educational tool that can actually decrease food waste.

5 Summary

We gathered the following insights from our study results:

(1) By analyzing the questionnaire before and after the experiments, the effectiveness of the game was clarified.
(2) We found that it was possible to subdivide consumers according to their buying behaviors regarding milk, as revealed in the consumer questionnaire.

(3) We were able to effectively compare milk waste between the cases with and without the one-third rule in this game. More waste was created when the players were under the rule. Thus, we saw the importance of reconsidering the impact of the one-third rule.
(4) We were able to develop a serious game that can be used effectively to enhance consumer consciousness around decreasing food waste.

References

1. Ministry of Health, Labour and Welfare: National Health and Nutrition Survey, Japan (2016)
2. Keizai, N.: Hokuren's first raw milk disposal, news (2006). Accessed 18 Mar 2006
3. Japan Dairy Industry Association Information. http://www.nyukyou.jp/detail/farming/farming01.html
4. Sato, M., Mizuyama, H., Nakano, M.: Milk supply chain management game for waste reduction. In: Naweed, A., Wardaszko, M., Leigh, E., Meijer, S. (eds.) ISAGA 2016, SimTecT 2016. LNCS, vol. 10711, pp. 302–314. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-78795-4_21
5. Gumus, M., Love, C.E.: Supply chain sourcing game: a negotiation exercise. Decis. Sci. J. Innov. Educ. **11**, 3–12 (2013)
6. De Caluwé, L., Geurts, J., Kleinlugtenbelt, W.J.: Gaming research in policy and organization: an assessment from the netherlands. Simul. Gaming **43**(5), 600–628 (2012)
7. Fuglseth, M.A., Grønhaug, K., Jörnsten, K.: Students' ability to apply their knowledge in a gaming exercise: an exploratory study. Scand. J. Educ. Res. 1–21 (2016). https://doi.org/10.1080/00313831.2016.1212255