Original Paper

Evaluation of the Loss of Dried Seaweed (*Nori*) in Packaged Rice Balls (*Onigiri*)

Hiroaki KITAZAWA[1,*], Rina KINOSHITA[1], Akari OTSUKA[1], Haruka SATO[1], Rio YAMAMOTO[1], Asako YAMADA[1], Yasushi KYUTOKU[2] and Itaru KITAZAWA[3,4]

Food remaining inside the packaging of commercial foods can cause food loss. Therefore, packaging must be improved in the near future to reduce the food loss. To determine the key improvements necessary, the current trends in relation to food loss through residual foods and their causes should be clarified for each packaged food. In this study, we focused on a typical triangular rice ball called *onigiri*, which has been estimated to be sold multibillion times in Japan annually. We estimated the amount of food waste from the dried seaweed (*nori*) used to envelope the *onigiri* remaining between the layers of packaging film. The results obtained from five *onigiri* suggested that the average mass of food waste from *nori* remaining between the layers of the packaging film was 47.6 mg. Consequently, when the number of distributed *onigiri* per year in Japan was assumed to be 1.0, 2.5, and 5.0 billion, the amount of residual *nori* per year in Japan was predicted to be 47.6, 119.0, and 237.9 Mg (= tons), respectively. Because the certainty of opening the packaging was also suggested to affect the amount of residual *nori*, we also compared the shape and heat-sealing pattern of the packaging film before and after opening the product. However, the differences in the packaging films were not significant and did not affect the amount of residual *nori*. Thus, to reduce food waste from residual *nori* for similar *onigiri* products, the fundamental packaging design, including the mechanism for enveloping rice balls, must be reconsidered.

Keywords: aquatic resources, film packaging, food loss, user-friendliness of packaging, waste treatment

[1]Laboratory of Food and Packaging Sciences, Department of Food and Nutrition, Faculty of Human Sciences and Design, Japan Women's University, 2-8-1, Mejirodai, Bunkyo-ku, Tokyo 112-8681, Japan
[2] Research and Development Initiative, Chuo University, 1-13-27, Kasuga, Bunkyo-ku, Tokyo 112-8551, Japan
[3]Katsuragi Elementary School, 689, Karima, Tsukuba, Ibaraki 305-0822, Japan
[4]Present affiliation: Teshirogi Junior High School, 5-10, Matsushiro, Tsukuba, Ibaraki 305-0035, Japan
*Corresponding author: Hiroaki Kitazawa. E-mail: kitazawah@fc.jwu.ac.jp
This study is expanded research on "How Much *Nori* from *Onigiri* Sold at Convenience Stores is Lost?" assigned as summer homework for Katsuragi Elementary School, Tsukuba, Japan in 2021 by the last author. In addition, part of this study was presented at the 33rd Annual Meeting of the SPSTJ.

1. Introduction

The packaging of commercial foods plays a vital role in reducing food loss, primarily by protecting the packed food. For example, plastic films with gas-barrier properties have been developed to maintain food quality[1]. In addition, cushioned packaging has been suggested to reduce the loss of soft foods such as fresh produce during transportation[2]. Packaging has another function related to user friendliness; user-friendly packaging might help in reducing food loss. An example is the application of liquid-repellent technologies in food packaging materials[3),4]. This technology is typically user-friendly and contributes to reduction in food loss as well as the environmental load related to waste treatment[5].

It is increasingly important to consider packaging designs that reduce food loss. To achieve this goal, we must first understand the current situation of food loss caused by residual foods, byproducts, and/or packaging. However, few studies have investigated the relationship between the type or shape of packaging and residual food, except for the previous study on dairy products by Klein et al.[6]

Thus, in this study, we focused on *onigiri* rice balls because this product was estimated to sell at multibillion units (= 10^9) in Japan every year, according to some press materials[7)–9]. Regarding the technologies to reduce food loss related to this product, although packaging for moisture control[1], temperature-controlled supply chain[10], and food additives[11),12] have been developed to prolong the shelf-life of the main body, that is the cooked rice and ingredients, the loss of dried seaweed (*nori*) from *onigiri* has not been discussed. The most commonly marketed *onigiri* products are triangular and packaged in plastic films (**Fig.1**). To prevent moisture absorption by *nori*, the rice balls and *nori* are separately placed inside the layered film until just before opening[13]. However, in the process of opening the package, some pieces of *nori* are torn and remain between the layers of the film. Because it is one of the major aquatic resources of Japan and its supply is sometimes unstable[14], it is worth estimating the amount of *nori* remaining inside the packaging. For typical *onigiri*, we estimated the amount of *nori* that remained between the packaging film layers. In addition, the amount of annual food waste from residual *nori* in Japan was extrapolated.

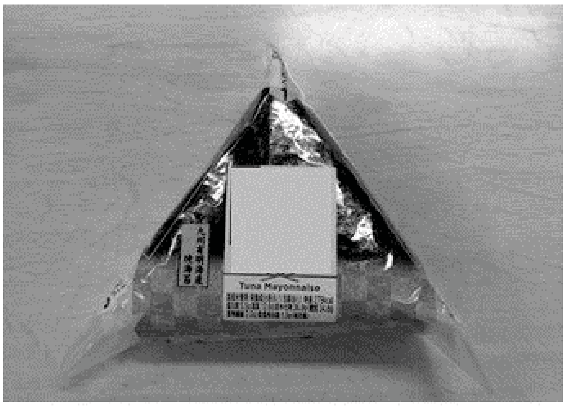

Fig.1. Typical triangular *onigiri* in Japan.

2. Materials and Methods

2.1. Details of tested *onigiri* and classification of the type of packaging

We purchased triangular and *nori*-separated *onigiri* (**Fig.1**) from three supermarkets (Product A−C) and two convenience stores (Product D and E) in Tokyo, Japan. Five *onigiri* products were purchased from each store. The average mass and size of *nori* sheets were approximately 1000 mg and 189 × 94 mm, respectively. The ingredients of the fillings of all *onigiri* were tuna and mayonnaise. The packaging film consisted of an inner and outer layer, which were made of polyethylene terephthalate-laminated polypropylene. The packaging film of all products had a label made of paper. It has been suggested that differences in the certainty of opening the packaging film for each product may affect the amount of residual *nori*. Therefore, we opened the packaging film of each product without tearing and removed the rice balls from the packaging. To classify the packaging film according to differences in shape and heat-sealing patterns, we then observed and drew the geometric nets of the inner layer for each product. The temperature was maintained at approximately 20 °C during the experiment.

2.2. Calculation of the amount of *nori* that remained within the film

The packaging was opened following the order (1−3) indicated on each packaging film. We then enveloped the rice ball with a sheet of *nori*. Next, the enveloped rice ball was removed and the mass (mg) of the film containing small pieces of *nori* (W_1) was measured using a balance (GR-300, A&D, Tokyo, Japan). Thereafter, small pieces of *nori* between the layers of the film were flushed with deionized water. The film without *nori* pieces (W_2) was dried using a drying oven (OFX-70, AS ONE, Osaka, Japan) at 40 °C for a week and then measured using the abovementioned balance. Thus, the mass of residual *nori* (mg) within the film was calculated ($W_1 - W_2$). Each product was measured with five replicates. Considering the variability of the certainty of opening the packaging film, we also observed the tearing and heat-sealing patterns of the outer layer using the pieces obtained after tearing.

2.3. Extrapolation of the loss of *nori* in *onigiri*

As mentioned earlier, some press materials have suggested that the total amount of *onigiri* produced in Japan per year reaches multibillion units (= 10^9)[7)–9)]. However, it was difficult to evaluate the production of triangular *onigiri* with dried *nori*, strictly because several types and shapes of products are produced and sold in Japan. For example, some *onigiri* are barrel-shaped and some are enveloped by *nori* directly[14)] inside the packaging. Based on these facts, we estimated the amount of residual *nori* while assuming the number of *onigiri* produced to be 1.0, 2.5, and 5.0 billion units. We calculated the minimum, average, and maximum mass of the residual *nori* by multiplying the masses estimated as described in section **2.2** with the number of *onigiri* produced.

2.4. Statistical analysis

To compare the amount of residual *nori* among different products, the Steel–Dwass test was conducted to determine the statistical difference among the products because homogeneity in variance was not considered. Statistical tests were performed using an add-in statistical software (Bell Curve for Excel version 4.04; Social Survey Research Information, Tokyo, Japan). The significance level for the tests was set at 0.05.

3. Results and Discussion

3.1. Differences in the packaging film of each product

The geometric nets of the inner layer and the heat-sealing patterns of the inner and outer layers are shown in **Fig.2**. Several differences were observed between the products. For example, the packaging film of the products A, C, and D contained areas that were heat-sealed in the lateral direction, whereas that of product B did not contain such areas. In addition, the lateral areas of C and D were connected to another sealed area along the film edge. In products A and E, these connections were either incomplete or unclear.

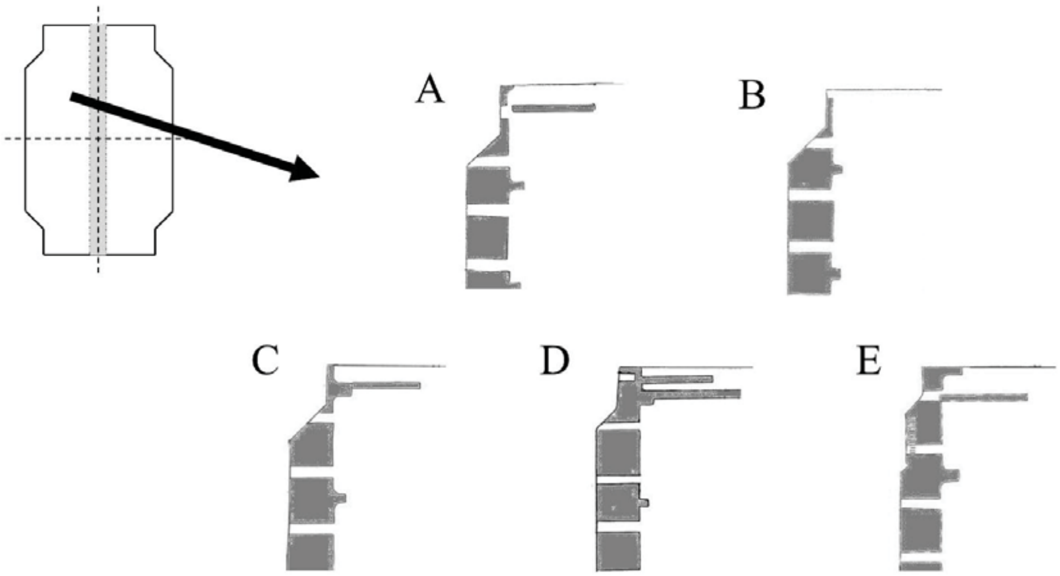

Fig.2. Differences in the heat-sealing pattern and the shape of the edge of the inner and outer layers of the packaging film. The dark gray areas in A–E show the heat-sealed areas between the inner and outer layers. The light gray area in the center of the upper-left figure indicates the overlapping inner layer.

The parts of the outer layer that were heat-sealed were classified into three patterns (**Fig.3**). The heat-sealing pattern for products A–C were linear, and the shape of the torn film pieces was almost linear. In product E, the heat-sealing pattern was similar to those of products A–C. However, the film also had perforated lines following a triangular outline. Consequently, the shape of the torn film piece was thicker than those of A–C along the triangular outline. The heat-sealed pattern in product D was a waveform with two cross sections. The shape of the film piece after tearing was also a waveform.

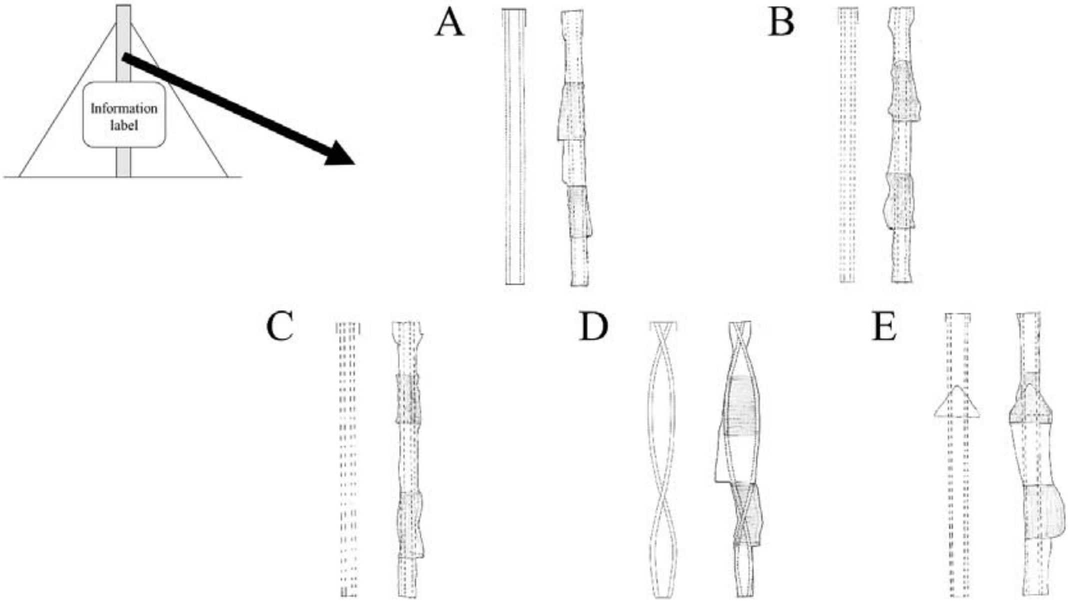

Fig.3. Differences in areas of the outer layer (indicated by dotted lines) that were heat-sealed for ease of tearing open the package (left) and pattern after tearing the outer layer (right) in each product. Light gray areas show the product information label. The triangle in the outline of product E packaging indicates a perforation line.

3.2. Effect of the difference in the amount of residual *nori*

The average mass of the residual *nori* in products A–E were 60.7, 40.1, 58.2, 36.6, and 42.2 mg, respectively (**Fig.4**). However, no significant differences were observed between the products. The minimum, average, and maximum mass of the residual *nori* from the five products were estimated at 29.5, 47.6, and 71.9 mg, respectively, which were equivalent to 3.0%, 4.8%, and 7.2%, respectively, of the average mass of *nori* among the products.

In section **3.1**, several differences observed in the shapes and heat-sealing patterns of the inner layer of the packaging film are described (**Fig.2**). The heat-sealed areas and the shape of the film piece after tearing the outer layer were classified into three patterns (**Fig.3**). These observations may be closely related to the separation of *nori* from the inner and outer layers of the film. Therefore, we expected each difference to affect the mass of the residual *nori*. However, the results obtained thus far suggest that the difference between the inner and outer layers was not affected by the amount of residual *nori* between products.

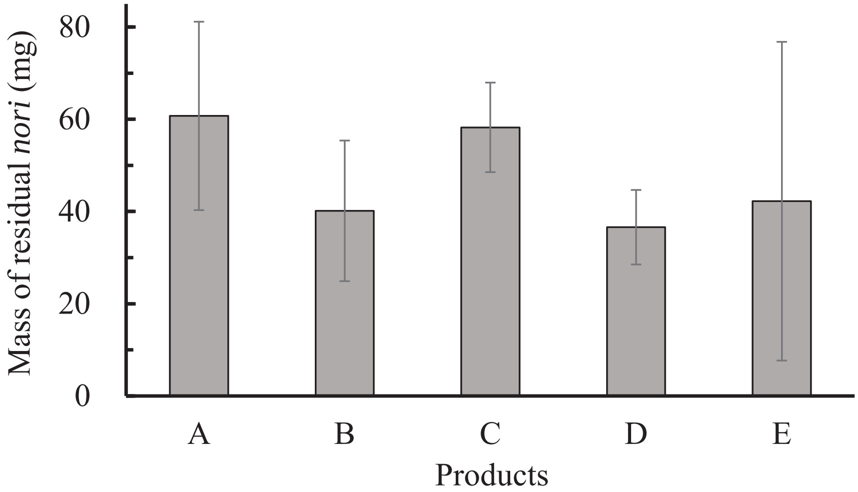

Fig.4. Relationship between the differences between the tested *onigiri* products and mass of residual *nori* from the products. Error bars show standard deviation (n = 5). No significant differences were observed between the products according to the results of the Steel-Dwass test ($p < 0.05$).

3.3. Extrapolation of the loss of *nori* from *onigiri*

We extrapolated the loss of *nori* from *onigiri* products while considering the assumptions described in section **2.3**. The results of this extrapolation based on the measured minimum, average, and maximum mass described in section **3.2** are shown in **Table1**. For example, considering that the approximate water content of dried *nori* and seaweed are 2.3%[15] and 85%[16], respectively, the loss of raw *nori* from 2.5 billion *onigiri* is estimated to be 4397.8 Mg (119.0 × 85.0 / 2.3); this value is comparable to approximately 2.2% of the amount of aquacultured raw *nori* in 2023 in Japan (201,100 Mg)[17]. As raw *nori* is also used to manufacture foods other than *onigiri* (e.g., *tsukudani*), this loss should not be ignored from the viewpoint of the protection of aquatic resources, considering the instability[14] and decrease in *nori* production[17),18].

Table1. Simulated *nori* loss (Mg = ton) in triangle-shaped *onigiri*s with dried *nori*.

Assumed *onigiri* production per year ($\times 10^9$)	Applied value*		
	Minimum	Average	Maximium
1.0	29.5	47.6	71.9
2.5	73.7	119.0	179.8
5.0	147.4	237.9	359.5

*Obtained from the results of **3.2**.

4. Conclusion

Our results suggest that the presence of residual *nori* is a consequence of the packaging used for triangular *onigiri*. To reduce food loss due to the residual *nori* from this type of product, it is necessary to change the fundamental method of using *nori* to envelope *onigiri*. Comparing differently shaped *onigiri* products may be effective in determining the optimal method. Moreover, it is worth investigating the effect of information labels on the certainty of opening a packaging film. This study could be positioned as advanced research to quantitatively estimate how the food remaining in packaging contributes to the loss of foods, especially liquid foods, such as sauces and salad dressings. In addition, this study demonstrated that the user-friendliness of packaging is related to food loss, and much attention has been focused on the protective function of packaging instead. Our future research will focus on determining the factors that improve food packaging, especially in terms of user-friendliness.

References

1) K. Nagai, Plastic films for food packaging applications and their gas barrier mechanisms, *Seikei-Kakou*, **34**(4), p.118 (2022)

2) M. Al-Dairi, P. B. Pathare, R. Al-Yahyai, U. L. Opara, Mechanical damage of fresh produce in postharvest transportation: Current status and future prospects, *Trends in Food Science & Technology*, **124**, p.195 (2022)

3) K. Manabe, Development of liquid-repellent surfaces to slip off water and oil, *Journal of Packaging Science and Technology, Japan*, **33**(1), p.19 (2024)

4) Y. Matsukawa, Functions and applications of super-repellent technology, *Journal of Packaging Science and Technology, Japan*, **33**(1), p.37 (2024)

5) T. L. Oldfield, E. White, N. M. Holden, An environmental analysis of options for utilising wasted food and food residue, *Journal of Environmental Management*, **183**(Part 3), p.826 (2016)

6) M. Klein, C. Werner, M. Tacker, S. Apprich, Influence of Packaging Design on Technical Emptiability of Dairy Products and Implications on Sustainability through Food Waste Reduction, Sustainability 16(15), 6335 (19 pages) (2024)

7) T. Shindo, *Sebun Irebun de Ichiban Ureteiru Onigiri wa? Chihou ni Yotte Sawa Aruno? Daichousa!* (What is the best-selling rice ball at 7-Eleven? Are there differences depending on the regions? A large-scale survey!), https://intojapanwaraku.com/rock/gourmet-rock/33864/ (2019) (Accessed: Sep. 10, 2024)

8) Seven & i Holdings, GREEN CHALLENGE 2050, *Sono Genzaichi to Mirai-eno Tenbo* (GREEN CHALLENGE 2050: Its current status and future prospects), https://www.7andi.com/company/challenge/12688/2.html (2020) (Accessed: Sep. 10, 2024)

9) N. Nakamura, *Sebun Irebun 50-nen, Kiki kara Umareta Onigiri 20-Okuko, Konbini Taizen 1* (7-Eleven over 50 years, 2 billion *Onigiri*s born from a crisis, Compendium of Convenience Stores 1), https://www.nikkei.com/article/DGXZQOCD092IA0Z00C24A4000000/ (2024) (Accessed: Sep. 10, 2024)

10) S. Mogi, The distribution of food, *Journal for the Integrated Study of Dietary Habits*, **11**(2), p.116 (2000)

11) H. Koiso, Food additives to control microorganisms, *Japanese Journal of Food Microbiology*, 28(1), p.1 (2011)

12) M. Hori, Survey on nutrients and food additive labeled on commercially sold rice balls (2), *Bulletin of Gifu City Women's College*, (68), p.33 (2018)

13) Seven & i Holdings, *Sebun Irebun no "Temaki Onigiri" wo Zenmen Sasshin* (Complete Renovation of Hand-Rolled *Onigiri*s of 7-Eleven), https://www.sej.co.jp/dbps_data/_material_/_files/000/000/019/382/20170329.pdf (2017) (Accessed: Sep. 10, 2024)

14) Ministry of Agriculture, Forestry and Fisheries of Japan, *Onigiri ni Kansuru Chosa ni Tsuite* (About Survey on *Onigiri*) (2016) https://www.caa.go.jp/policies/policy/food_labeling/other/pdf/160613_shiryou4.pdf (Accessed: Sep. 10, 2024)

15) Ministry of Education, Culture, Sports, Science and Technology of Japan, Food composition database ver. 2023, https://fooddb.mext.go.jp/index.pl (2023) (Accessed: Sep. 10, 2024)

16) M. Uchida, Fermentation of seaweeds and its application, *Journal of Brewing Society of Japan*, **106**(2), p. 71 (2011)

17) Ministry of Agriculture, Forestry and Fisheries of Japan, *Reiwa 5 Nendo Gyogyo·Youshokugyo Seisan Toukei* (Statistics of Fisheries and Aquaculture Production in 2023) (2024) https://www.maff.go.jp/j/tokei/kouhyou/kaimen_gyosei/index.html (Accessed: Sep. 10, 2024)

18) M. Sano, Current status and trend of marine aquaculture industry, *Japanese Journal of Fisheries Economics*, **66**(1), p.89 (2022)

(Received: 26 September 2024)
(Accepted: 5 December 2024)

包装されたおにぎり製品における海苔のロス評価

北澤 裕明[1,*]、木下 理名[1]、大塚 朱莉[1]、佐藤 陽香[1]、
山本 莉緒[1]、山田 麻子[1]、久徳 康史[2]、北澤 いたる[3,4]

包装容器内に取り残される食品は、食品ロスの一因となることから、近い将来、そのような取り残しの発生を抑制するための包装容器の改良が進められるものと考えられる。改良点を抽出するためには、取り残しの現状および発生要因を把握することが重要である。本研究では、我が国において年間数十億個販売されていると推定される一般的な三角形のおにぎり製品に着目し、開封後、包装フィルムの間に残される海苔の量を推定した。5 つの製品を対象とした調査の結果、開封後に取り残される平均の海苔の量は 47.6 mg であった。この評価結果を適用し、仮に流通するおにぎりの個数を年間 10 億、25 億、50 億とすると、それぞれ 47.9 Mg（＝トン）、119.0 Mg および 237.9 Mg の海苔が取り残されるものと試算された。なお、開封の確実性が取り残しの発生に影響を及ぼす可能性が推定されたことから、開封前後における包装フィルムの形態、開封のためのヒートシールパターンなどについても観察した。しかし、製品ごとのそれらの違いは軽微であり、取り残される海苔の量に影響を及ぼさないことが示唆された。従って、本研究において対象とした形状の製品において取り残される海苔の量を低減するためには、ご飯に海苔を巻くための機構を含む根本的な包装設計の見直しが必要といえる。

キーワード：食品ロス、水産資源、廃棄物処理、フィルム包装、包装の利便性

※本研究は、最終著者が 2021 年に光輝学園つくば市立葛城小学校における夏休みの自由研究として取り組んだ「コンビニのおにぎりののりはどれくらいロスしているか」を発展させたものである。また、本研究の一部は日本包装学会第 33 回年次大会で発表した。