# DEVELOPMENT OF A NEW REFLECTIVE MATERIAL AND ITS APPLICATIONS TO VARIOUS TYPES OF SOLAR COOKERS IN LOW PRICE RANGE

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**Abstract**
The author has commercialized several products of solar cookers mainly as educational tools for school children in cooperation with an aluminum foil company, a carton case company and a trading company. In 2013, we developed a multi-layer film to be used for reflective material for solar thermal applications. By attaching the film to the corrugated plastic board with a special technique, we made tough, light-weight and less expensive material for the body of a panel type solar cooker which was originally made of corrugated cardboard. We have used it for the field research to verify its compatibility for the use in Ethiopia and obtained many fruitful responses from 30 families. After a few modifications requested from the Ethiopian people, we have commercialized it in Japan. Main customers are schools and NPO's. Recently we designed a concentrator type solar cooker with the same material. The prototype model is 1.1m in diameter for the practical cooking power and has polyhedron surface for the safety and its total weight is less than 10kg including the supporting parts. While most of the existing concentrator type solar cookers are in the high price range, ours will feature the challenging price in the market.

**Key words**: Renewable energy, solar cooker, educational workshop, reflector

## 1.0 Introduction

Ashikaga Institute of Technology (AIT) has designed several solar cookers of different types through the collaborative researches with the companies in the neighboring region. Because the number of lecture deliveries adopting the solar cooker reaches forty a year, some of the cookers were made into products as educational materials by Showa Rikagaku Kikai Co. Ltd. (SRK). A consulting company, myclimate Japan Co. Ltd. co-financed by ECONOS Co. Ltd, and myclimate Foundation, a world leading voluntary carbon offset provider, based in Zurich, Switzerland noticed the potential application of the AIT Educooker003, a panel type solar cooker, as a tool to support people suffering from fuel shortage in developing countries. SRK and mycJ organized a consortium to apply for the project commissioned by the Ministry of Foreign Affairs of Japan, and AIT joined it as an advisor. For the investigation, we prepared the new reflecting material under the collaboration with Toyo Aluminum K. K., the largest aluminum foil company in Japan. The present paper consists of three parts, one is on the design, improvements and performance of our modified solar cooker from the educational version (Educooker003), the second is on the results of our on-site survey in Ethiopia using our improved panel type solar cooker (Educooker003R), and the last is the application of the same material to the reflector of a concentrator type solar cooker designed by Ashikaga Institute of Technology

*Fig. 1: Setting of Educooker003 for low solar elevation.*

*Fig. 2: Setting for high solar elevation*

### 1.1 Design of Educooker003

Educooker003 was designed and made into product in 2007 as a teaching material to be used in science classes in elementary or junior high schools by enlarging the size 10% from the previous version 002. To adapt to the use in Japan where the sun elevation changes largely with the seasons the shape was designed carefully calculating the concentration and the robustness by ray-tracing software. Its dimensions were determined to meet the size of the cylindrical mess kit for the cooking pot which is available throughout Japan. The shape of the body before set-up is a 1m by 1m square with four slits and folding lines. The leftovers coming from the processing is little. The total number we produced and sold reaches three thousand. The material of the original panel type cooker is made of cardboard with aluminum-metallized film. .It can boil 500ml of water averagely in 90 minutes through the year as shown in the figure 4.

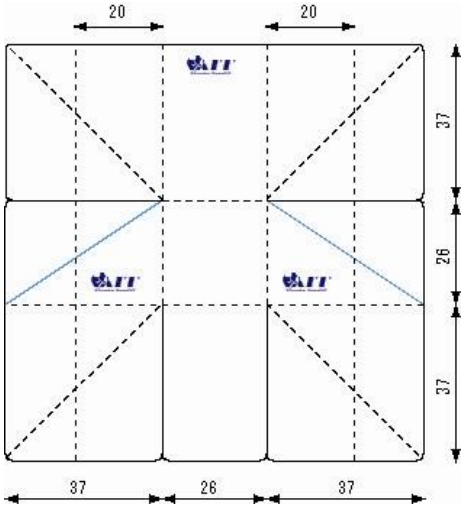


*Fig. 3 The plan of the Educooker003*

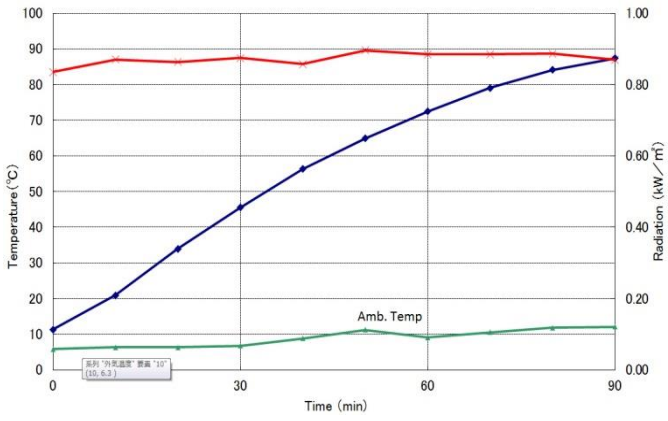


*Fig. 4 Temperature rise on Dec 24 around noon*

### 1.2 Modification to Educooker003R for the First Investigation in Ethiopia

To improve the durability and reflection rate, new laminated film consisting of aluminum-metallized PET film and aluminum foil developed especially for our solar cooker was manufactured by Toyo Aluminum K. K. The material for the body was changed to plastic (PP) and machined into the shape by Ohki Carton Case Company. The performance at the site was simulated by the ray tracing software before carried into Ethiopia. The results of the simulation are shown in the table 1 and in the figure 5.

*Table 1. Concentration by the analysis*

| Season | Spring/Fall | Summer | Winter | Vertical Sun Light |
|---|---|---|---|---|
| **Concentration Rate** | 73% | 66.6% | 84.5% | 61.9% |
| **Concentration Factor** | 6.6 | 6.1 | 6.3 | 6.8 |

The size of the pot used in the analyses is 24cm in diameter and 20cm in depth.

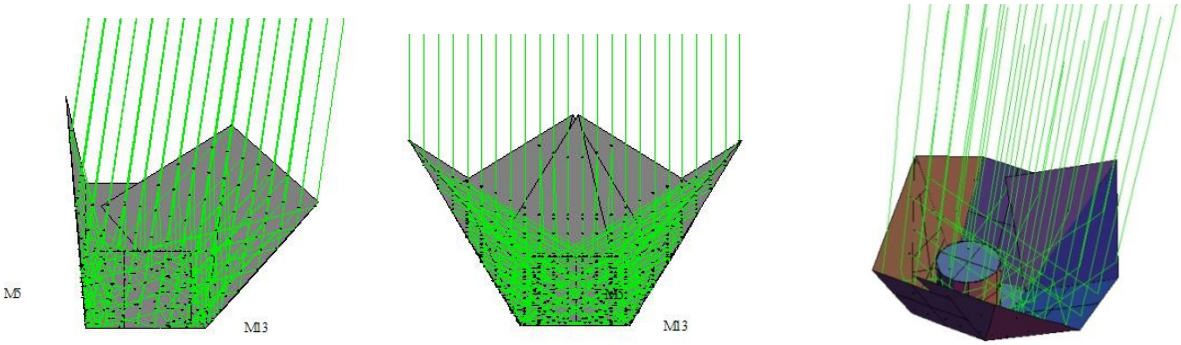

*Fig. 5 Example of simulation for the sprint/fall equinox in Ethiopia*

### 1.3 Improvements of the Cooker for the Second Investigation

From the responds of the first visit to Ethiopia we found that the largest one made of 1.2m square sheet is most suitable for the use by average Ethiopian family in the refugee camps, and the size of the modified version was unified to that of the largest one. We further improved the stability for strong wind in Ethiopia in winter for the second visit by changing the cutting shape without decreasing the projection area to the sun. In the demonstration in the first visit, we succeeded to cook 500g of pasta with the same amount of water and oil in 90 minutes by our largest cooker made of a 1.2m by 1.2m sheet. Before the investigation, we could not identify the benefit of foldability for compactness, but from the questionnaire survey we realized that some people want it to be folded in smaller size when they store it in their house at night. For the second visit, two folding lines were added to the cooker to be folded in 32 cm by 76 cm flat rectangular shape.

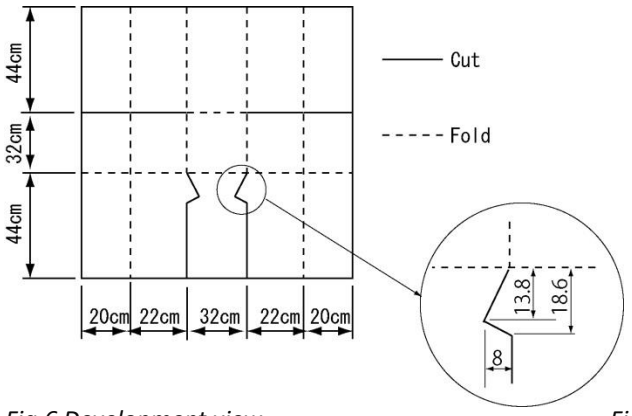


*Fig.6 Development view.*

*Fig. 7 Improvement for the resistance to the wind*

### 1.4 Government of Ethiopia Policy Plan

The Ethiopian government, aiming to break-away from the poverty, has created a 5-year plan called "Growth and Transformation Plan (hereinafter referred to as GTP)". In GTP, the government has a chapter on "Alternative Energy Development and Promotion". It indicates the policies to promote alternative energy that contributes to curbing deforestation and improving the indoor environment, and the Ministry of Energy is tasked to mainly tackle these issues. Other than those mentioned above, the continuous increase in the number of refugees is also one of the causes of the deforestation.

Ethiopia has been receiving 420,000 refugees and has 26 refugee camps opened. In the entire refugee camps, the environmental issue attracts prominent attention as a serious problem. Cutting-down trees for firewood in the host communities by refugees has become a serious problem and conflicts between refugees and the host community have been occurring. Regardless of assistances from various support groups, steep rise in fuel cost and budget limitation will have been making it difficult to find radical solutions to the situation. Spreading "Solar Cooker" a cooking device using the ultimate renewable energy source in Ethiopia, is expected to promote introduction of renewable energy mentioned in GTP and contribution of forest preservation. Furthermore, it is conducive to solve the problems associated with the refugee flow in.

### 1.5 Purpose and Method of the Survey

The field research of the solar cooker to verify its compatibility has been divided into two parts. In the first research, the solar cooker produced as pilot model based on the simulated amount of insolation in Ethiopia was provided. In the second research, the improved model reflecting the feedbacks from the first research was arranged. The research sites are two in total: Jijiga refugee camps in Somali and rural areas in Tigray.

The first research in Ethiopia (refugee camps) was conducted with the tremendous help from an NGO (Gaia Association), which is in charge of fuel supply in Jijiga refugee camps. Targeting at three refugee cam（Kebribeyah, Awbere and Sheder）and choosing 10 normal-size households from each camp（30 households in total）, we conducted the research on food and fuel supply through interview. Moreover, the research to verify the cooker's compatibility was managed by the distribution of some pilot model products in different size and color to each participant and by recording of usage for their daily cooking.

Fig. 8: Teaching the instructors from Gaia

Fig. 9 Refugees in Jijiga camp

### 1.6 Association

For the research in rural areas in Tigray, the local university, Mekelle University, was in charge of conducting the same research on local people.

Based on the feedbacks from the first research in refugee camps, we made some improvements in size, wind resistance and the way of folding to the pilot ones and prepared 10 pieces of "Improved solar cooker" in Japan to use in the second research.

In the second research in refugee camps, 3 households from each camp (9 household in total) out of 30 households who had participated the first research were selected and they used the improved model and further feedbacks were obtained.

## 2.0 Results of the Survey

Outcomes of the two field researches reveal that almost all of the local typical food can be cooked with our solar cooker and 80% of the refugees give positive feedback on the product. The main reason is "Can save precious fuel", others are "No smoke" and "Safe to use".

In the research in Tigray, we found out that people surrounded by forests or conservative people are unwilling to accept our solar cooker. Contrary to our expectation, it turned out that cities and suburbs where people are compelled to purchase fuel are in demand. Another fact we noticed is that while the refugees do not hesitate to

cook outside, some middle class urban people are unwilling to cook in the inner court used by several families in common.

In the dissemination of the solar cooker, crucial issues to be resolved are disclosed.

The first issue is accessory procurement such as black pots or black paints, plastic bags, etc. Therefore, in the spread of the solar cooker, the strategy to provide accessories for the users should be developed.

*Fig. 10 Favorable responses from the middle class family in Addis Ababa.*

*Fig. 11: Preparatory Practice at an NGO in Addis Ababa*

The second issue is the way of use of the solar cooker itself. For example, in cooking with the solar cooker, people need to put all ingredients into pots at once before cooking and once pots are set on the cooker, people cannot open rids (stir) until the cooking finishes. Meanwhile, generally Ethiopian people have custom to stir quite often in cooking, and they often show strong rejection to the use of the solar cooker until they see and taste the result which is almost similar to the one cooked in conventional way. Furthermore, people have complaints on the following two points; 1) cooking with the solar cooker is limited between the hours from 10:00AM and 3:00PM due to sun elevation and 2.) the cooker cannot cook the full volume of big pots due to theoretical limitation. The first complaint can be resolved instantly if they know how to handle our cooker when the sun elevation is low as shown in the figure 1. Actually it can start cooking from 7:00AM because our cooker is designed to be used in Japan where the sun elevation changes largely with the season and it can cook even in Japanese mid-winter. But in the demonstrations in Ethiopia, we limited the usable time to simplify its setup. For the second complaint, we have to persuade the people that the size of the pot is determined to gain the concentration and not to contain the necessary amount of foods. In promotion of the solar cooker among people in Ethiopia, the encouragement activity and education of its usage are essential.

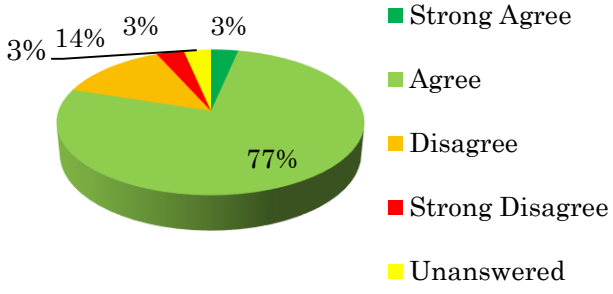


*Fig. 12 Response from the user in the first investigation*

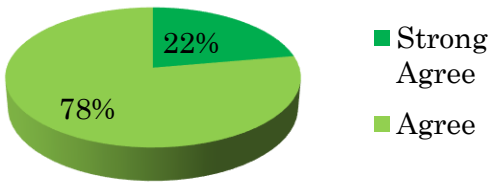


*Fig. 13 Response from the user in the second investigation*

Last of all, the establishment of distribution system is also one of the biggest issues to be resolved. In Ethiopia, distribution business has still not been put in place, when bringing new products into the market, everyone needs to search partners from scratch. In the event of receiving government or UNHCR supports as ODA project, we do not have to cover distribution in Ethiopia, however we need to confirm carefully.

In the dissemination of the solar cooker, although the market is expected to have high potential, all of the above-mentioned issues have to be resolved first certainly. Moreover, in order to drop the price of the solar cooker, on-site manufacturing should be considered.

### 2.1 Application of the Same Material to a Concentrator Type Solar Cooker

Because the reflection rate and the durability of the material used for the Educooker003R is quite high for that of the low price range, we attempted to apply it for the concentrator type solar cooker. The size of the prototype is determined from the size of the material sheet (1.2m by 1.2m) and we have to adopt the polyhedron shape because it is difficult to make a curved surface with the corrugated plastic board. We employed discretely approximated parabolic shape with the diameter of 1.1m and the focus length of 0.2m. In radius direction, it has five divisions and in circumferential direction, twelve divisions as shown in the figure 14.

### 2.2 The Performance of The Concentrator Type Solar Cooker

The surface of the corrugated cardboard/plastic is not completely flat but rather wavy because of its structure. For the reflector of a concentrator, the roughness of the surface is one of the dominant factors. For that reason, those materials are seldom used for the concentrator type solar cookers. But when the size of the reflector is not very large and the concentrator factor is relatively low as around twenty to thirty, and the length from the reflector to the pot is short as ours, the small roughness of the surface does to affect the concentration very much. Our new concentrator type solar cooker can cook two liters of stew in an hour while the panel type using the same material needs 1.5 hours to cook a liter of food as explained previously in section 3. The additional advantage of the polyhedron mirror is that it will never start the fire and it can heat the pot evenly.

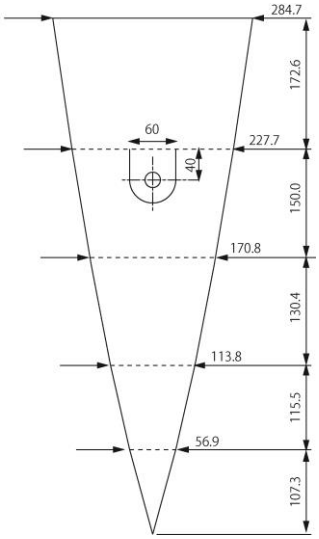


*Fig. 14: one of the twelve parts for the reflector*

*Fig. 15 Assembled concentrator type solar cooker*

### 3.0 Summary

By the several modifications applied to our original panel type solar cooker for the education in Japan reflecting the feedbacks from the two-time surveys, we made a durable and powerful enough solar cooker to meet the needs of average Ethiopian people and refugees in Ethiopia. By adopting the same material to the prototype concentrating reflector, we clarified the possibility to adopt it to the concentrator type solar cooker. We are now searching the new application of our tough, less expensive material other than solar cookers.