Solar Cookers in the People's Republic of China

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ABSTRACT

Owing to the unique high solar radiation in China, solar cookers are considered to be one of the solutions to the country's energy problems and are being actively developed. Utilization of solar cookers is not only a more sanitary method of cooking but is also more ecologically balanced. As it is obvious that they are better than using fires fuelled by dung, local farmers throughout China are willing to use solar cookers. The two types of solar cooker which have already been developed are the box-type and the concentrating-type. The latter type is more popular with Chinese farmers.

INTRODUCTION

Today, China like many other countries all over the world is short of energy. The Chinese government has therefore tried to overcome their problems through energy conservation measures and by research and development of new and renewable sources of energy, such as solar energy. One particular application of solar energy, the solar cooker, which is simple and easily made, is of great interest to the government, as well as to research and management agencies. The number of solar cookers has been increasing day by day and by the end of 1985, 60,000-70,000 of these were in use, bringing considerable benefits to many areas throughout China. Measurements and tests have shown that a solar cooker with a 1,000 W power can save on an average about 1,000 kg per year of firewood and straw used as living fuel. This is an important finding for areas where energy shortage is a pressing problem.

Solar Radiation Resources in China

China is situated in the northern hemisphere. Its territory is large and solar radiation resources are abundant, especially in Qinzang plateau, Xinjiang, Gansu, Ningxia, west of Yunnan and Sichuan, as well as in northern and north-eastern China. Among all these places, Qinzang plateau with its clean, thin atmosphere has the most solar radiation. The radiation value is 160-200 kcal/cm^2 per year and each year there are between 2,800-3,200 hours of sunshine, making it very suitable for solar energy utilization. In the south of Xinjiang, the west of Gansu, the north of Ningxia and the west of Inner Mongolia, the atmosphere is very dry and there are few clouds in the sky throughout the year. Thus there are up to 3,200 hours of sunshine per year, while the radiation value is 140-160 kcal/cm^2 per year. The distribution of China's abundant solar energy resources is shown in Fig. 1.

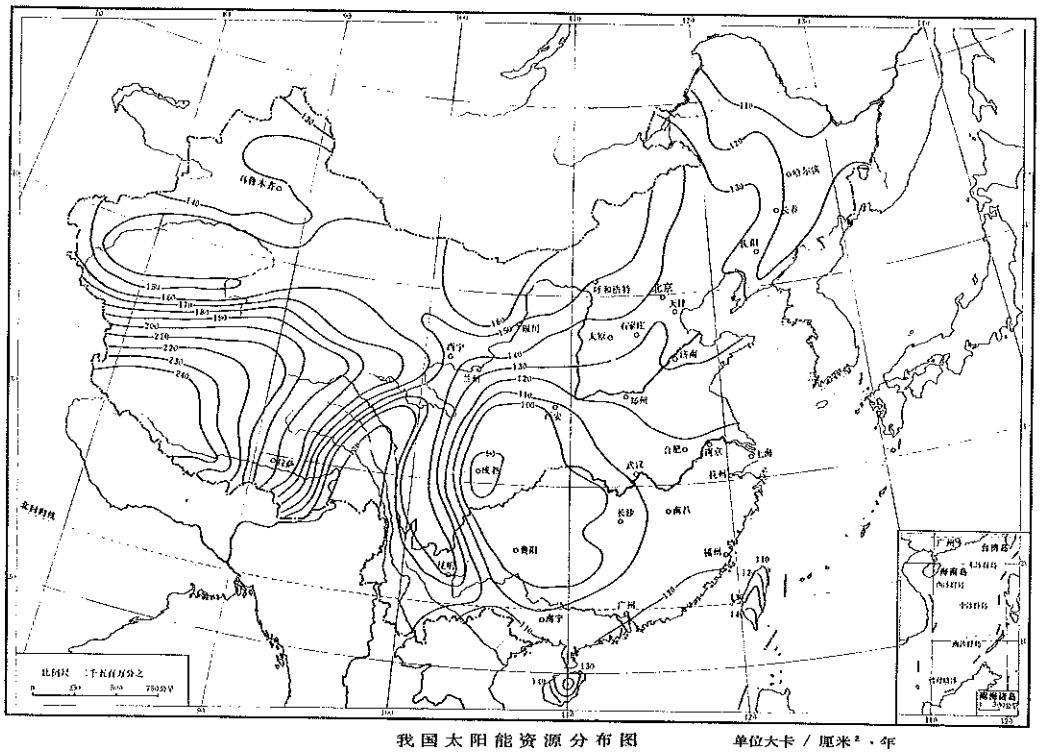

Fig. 1 Solar radiation distribution in China (kcal/cm² year).

Adoption of the Solar Cookers by Chinese Farmers

Chinese farmers have traditionally used firewood, grass and straw as living fuel. However, the increased rural population and the growing raw material requirements of light industry have caused serious shortages of living fuel in many districts and peasant households, as well as deforestation problems and ecological imbalance in some areas. As it is impossible to meet the increased demand for energy by fossil energy resources during this century, China has widely focussed on developing solar energy resources. As a result, solar cookers have been developed rapidly in the areas where a great deal of solar radiation exists.

The farmers' interest in the solar cooker is due to its simple construction, ease of operation and low cost. The solar cooker has, to some extent, solved the living energy problem of farmers in a number of communities. For example, in Sanzhai village in Lintan county south of Gansu province, each family has a solar cooker. In another village in Yongjing county of Gansu, all 188 families use solar cookers. This spares 200 tons of wood and straw per year. In the same county, Xiaolin community, energy from solar cookers accounts for 33 per cent of living energy consumed. Moreover, a large number of solar cookers is being used in Haian, Rugao of Jiangsu, Gai county of Liaoning, Hualong of Qinhai, Linxi of Hebei, Nizen of Henan, Linxia of Gansu, Jimosher of Xinjiang, Guzhen of Anhui, Haiyan of Ningxia, some areas of Inner Mongolia Autonomous Region etc. Recently Xizang also began to use solar cookers.

RESEARCH AND DEVELOPMENT OF SOLAR COOKERS IN CHINA

The solar cooker is a device that can convert solar radiation into thermal energy to cook food and boil water. Generally, two types of solar cooker have been developed in China, namely, the thermal box-type and the concentrating-type. The former has a design which uses the "greenhouse effect" i.e., sunlight enters the box through a transparent cover where it is converted to thermal energy in the coatings attached to the inner surfaces of the box. In this manner the temperature in the box increases to such an extent that it is possible to cook food and boil water. These solar cookers, of flat-plate collector type are simple in structure, low-cost, and convenient to use. But, because of low energy density, the temperature in the box is as low as 150-200°C. Sometimes, additional reflective mirrors are connected to the external side of the box in order to increase the amount of solar radiation going into the box. The box-type solar cooker is good for cooking foods but not for roasting or baking. Most of the concentrating-type solar cookers have a design which uses the principle of concentrating by reflective mirrors, in which sunlight is reflected and then concentrated at the bottom of the cooking vessel thus causing food to cook or water to boil. Generally the solar radiation collection area ranges from about 1.5 m^2 to 3.0 m^2. The temperature at the point of concentration ranges from about 400-1,000°C. The power is about 500-1,500 W and the efficiency is between 55 and 77 percent. This type of solar cooker can be used not only to cook food and boil water but also to roast meats and fry vegetables, etc. Therefore they are very popular with farmers.

In China, R&D of solar cookers began during the 1950s. But it was during the 1970s, when the oil crisis broke out, the solar cookers were seriously developed as a solution to rural energy problems. Many research institutes and other concerned organizations have carried out R&D of solar cookers. At first, box-type solar cookers were developed, these were followed by the concentrating-type with a central axis. In recent years, Chinese technicians have put forward a new design concept of concentrating-type solar cookers with an eccentric axis and have made trials in the hope of improving the original solar cookers with a central axis. Investigations were carried out on the selection of structure parameters in accordance with the principles of human engineering, and the optimal height of operation (Φ 130 cm), the optimal span of operation (Φ 75 cm) and minimum sun angle (Φ 25°C) of solar cookers which should be suitable for China were determined.

For basic body materials, fiber reinforced materials have been adopted to replace bulky concrete structures and to meet the design requirements of rigidity and intensity. Glass fiber reinforced plastic is representative of the type of light materials used but is a little more expensive than glass fiber reinforced cement. Another type of material, cast iron, which is used to make pots, is also suitable for solar cookers.

For reflective materials, a kind of aluminized polyester film was developed in Shanghai and Jiangsu. A tendency to replace aluminized glass mirrors, which are brittle, has taken place. Figs. 2 and 3 show a solar cooker with a glass mirror and with aluminized polymer film respectively.

In December 1981, a workshop on constructing solar cookers was held in Shanghai and as a result a number of technical parameters and other characteristics, reflecting the technical level of Chinese solar cookers, were agreed upon. These include:

1. Higher thermal conversion efficiency, $\eta > 50$ percent.
2. Proper temperature of spot, $T > 400$°C.
3. Diameter of spot suitable for cooking, $D \leq 12$ cm

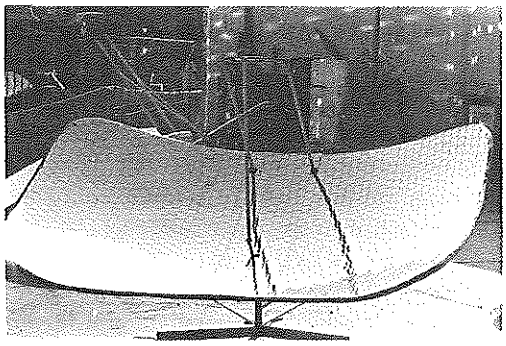

Fig. 2 Solar cooker with glass mirrors.

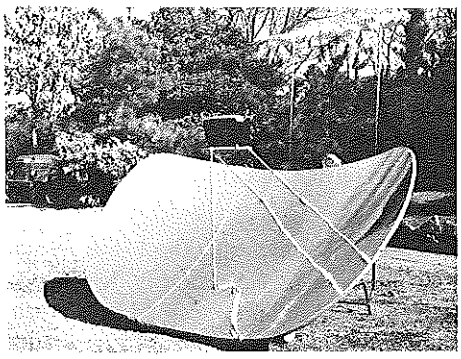

Fig. 3 Solar cooker with aluminized polyester film.

4. Power meeting the cooking surface, $W \approx 1{,}000$ W
5. Good light-collective surface with reflectance, $R > 80$ percent, its life, $T > 2$ years.
6. Proper rigidity and intensity of cooker's body and its life more than 5 years.
7. Reasonable price, ranging from 100 to 150 Yuan in RMB, depending on different materials adopted.
8. Easy to operate and maintain.

Another seminar held in Shanghai in November 1982 stimulated further R&D of solar cookers and a new design method called "triple arc design and analysis method" was developed by Chinese technicians. This enabled energy to be concentrated more effectively. Since then, many research units have developed a variety of solar cookers using different materials. A number of these won "Superior Solar Cooker" awards at the exposition held in Beijing in September 1983 (see Fig. 4). A few years ago, a rural research group was established to undertake design and development of solar cookers and later in 1986 it won "First Class" awards at the exposition in Beijing for its LZ model, LZT cast iron solar cooker. Now almost ten types of solar cooker are distributed all over the country and have gained wide acceptance. Moreover, the number of producers of solar cookers and the number of solar energy industries is on the increase.

Fig. 4 Exposition held in Beijing.

BOX-TYPE SOLAR COOKERS

Only a small number of box-type solar cookers is being used in China (see Fig. 5). They are found mainly in Louyan, Nizhen, Zhenzhou and Anyan of Henan, Dandong of Liaoning, Gansu and Tibet. There are also about 1,500 units of box-type solar cooker distributed in many counties in Shandong. Besides these, a type of box-type solar cooker developed in Nanchang has an additional reflective mirror outside of and adjacent to the box. This reflects more solar radiation into the box.

Most of the box-type solar cookers have two layers of transparent cover both of which are made of glass, otherwise the outside is made of glass and the inside made of plastic film. At the bottom of the box, there is an absorptive surface which usually consists of a flat black coating. Enamel is sometimes used for the absorptive coating. A layer of reflective film is often attached to the inside of the box, while insulation materials, such as glass fiber and expanded polystylene are lined on all sides and underneath the box.

Fig. 5 Box-type solar cooker being used.

CONCENTRATING-TYPE SOLAR COOKERS

The majority of solar cookers in China are the concentrating-type (see Fig. 6). These are usually central axis or eccentric axis solar cookers. The latter possesses not only a superior reflective body, but also greater cooking efficiency, and they are used extensively in China. The former have a larger angle between the focal plane and the bottom plane of the cooking vessel. Thus, some of the light is reflected outside of the cooking vessel and effects the cooking efficiency to some extent. Besides these, there are a few solar cookers in which the reflective body is in the shape of a parabolic column. The design and fabrication of this type is easier than the others, as long as a number of rectangular mirrors are arranged in the form of a parabolic column.

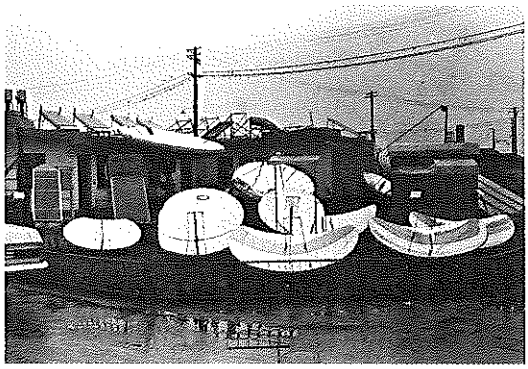

Fig. 6 Concentrating solar cookers.

In terms of external features, there are many varieties of concentrating-type solar cookers such as rectangle, square, umbrella, butterfly and lotus flower. Some can be folded and thus can be conveniently moved (see Fig. 7). Most concentrating-type solar cookers have hand-operated tracking systems. Three years ago a solar cooker suitable for baking cakes was developed in Xinjiang. Its novel structure is shown in Fig. 8. In the past, most solar cookers were made of concrete, nowadays light-duty structure materials such as fiber reinforced cement and plastics have been adopted. Although the solar cookers made of glass fiber reinforced resin or rigid plastics are a little more expensive than others, their light weight makes them the most suitable for Gansu,

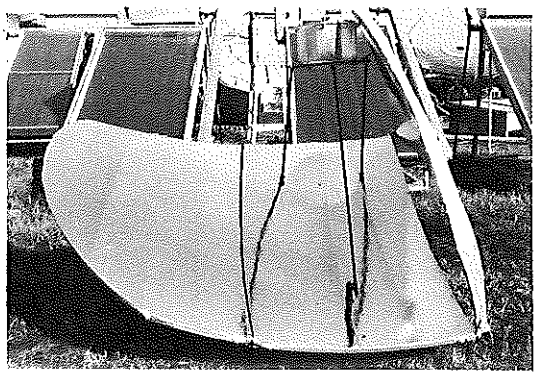

Fig. 7 Solar cooker that can be folded.

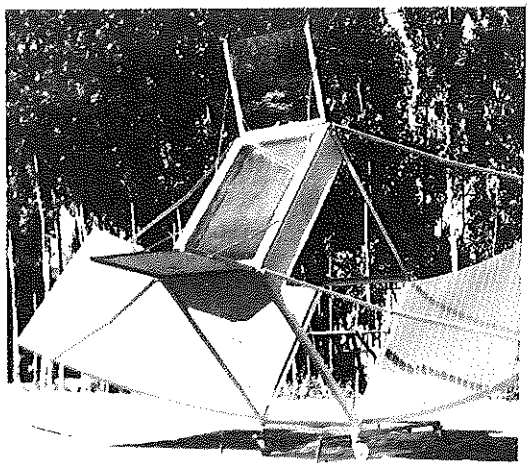

Fig. 8 Solar cooker suitable for baking cakes.

Xinjiang, Ninxia, Inner Mongolia and Tibet, as a portable cooker is required for these areas. Table 1 lists the characteristics of a number of solar cookers which have been developed in China.

Solar cookers similar to the model F775-B in Table 1 are being used in Nizhen of Henan, Longxi of Gansu, Lingxi of Hebei, Anyao of Guangxi, and some solar cookers made in Guzhen of Anhui are similar to the model ZNT-III. In addition, a Gan-8 model solar cooker made of chopped wood reinforced cement has been developed in Jiangxi, and pulp reinforced cement solar cookers were made in Hebei. Research and development of a GN model solar cooker, whose basic body consists of a local soil called magnesia was carried out at Gansu Natural Energy Research Institute. The GN-8 model solar cooker can be folded into the form of an easily excursionists and it won a "Superior" award at the solar cooker exposition in Beijing in 1986. In Jianghu of Jiangsu, Xian of Shanxi, Qufu of Shandong and Nizhen of Henan there are solar cookers which generate vapor for cooking. They are called vapor solar cookers (Fig. 9). The cooking chamber and solar collector are separate and therefore users need not cook out-of-doors. Thus, the food is prevented from outdoor dust contamination.

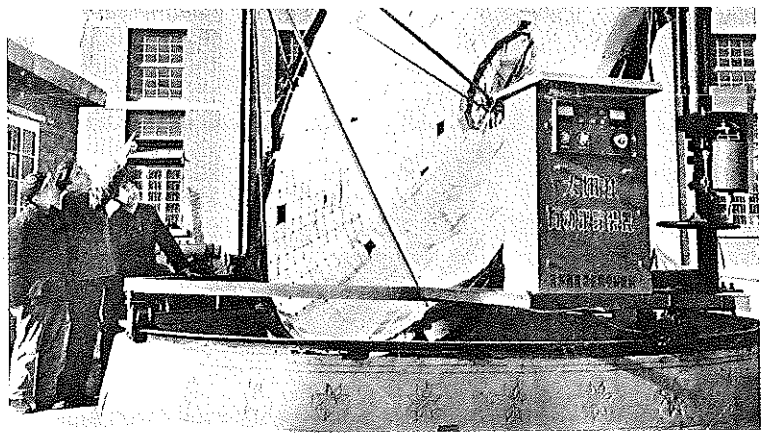

Fig. 9 Vapor solar cooker.

Table 1
Characteristics of some advanced solar cookers developed in China

Name	F775-B Concentrating Solar Cooker	ZNT-III Concentrating Solar Cooker	XET-1 Cast Iron Concentrating Solar Cooker	81-FB Folding Butterfly Solar Cooker
Model	F775-B	ZNT-III	XET-1	81-FB
Basic body materials	Steel bar reinforced concrete	Antibase glass fiber reinforced cement	Cast iron for pot	Glass fiber reinforced resin
Reflective materials	Aluminized glass	Aluminized polyester film	Aluminized polyester film	Aluminized polyester film
Area of spot	100 cm^2	145 cm^2	70 cm^2	na
Light interrupted areas	2.23 m^2	2.65 m^2	2.41 m^2	2.14 m^2
Focal length	775 mm	800 mm	800 mm	na
Power	1,316 watts	1,500 watts	1,555 watts	1,000 watts
Thermal efficiency	70%	70%	70%	na
Minimal solar height angle	30°	25°	20°	na
Height of operation	117 cm	125 cm	na	120 cm
Span of operation	65 cm	80 cm	75 cm	na
Gross weight	130 kg.	70 kg.	89.5 kg.	23 kg.
Cost	Low (100 Yuan in RMB, ≈ US$27)	Medium (100-150 Yuan, ≈ US$27-40)	High (about 150 Yuan, ≈ US$40)	na

HYBRID SOLAR COOKERS

This is a type of solar cooker combining the box-type with the concentrating-type, for example Henan's box-type solar cooker which has an eccentric axis concentrating device. It has a temperature higher than 500°C. The Kunmin's box-type solar cooker with a parabolic concentrat-

ing column also belongs to this category. The cooking vessel used with this type of solar cooker hangs on a shelf in the box, so it combines advantages of both concentrating-type solar cookers and thermal box solar cookers, i.e., it combines high energy density and rapid temperature increases with little loss of heat.

As rural energy problems have become more urgent and as the efficiency of solar cookers has improved, the Chinese government and Chinese farmers have taken more interest in this technology. At present a considerable amount of research and development work is being undertaken concerning prolonging the life of solar cookers (especially the life of reflective materials), reducing the cost, thermal insulation, storage and automatic tracking aspects. However, it is also important that the most appropriate type of cooking vessel for use with the solar cooker is developed. Without doubt the market for solar cookers in China will be very large in the future.

REFERENCES

1. Tu Yunzhang, *et al.* (1984), Summary of solar cooker research and development, *Solar Energy*, No. 2, p. 2, Beijing, China.
2. Jia Yingzhou, *et al.* (1983), *The Principle of Design and Manufacture for Concentrating Solar Cooker*, Energy Publishing House, Beijing, China.
3. Wang Changgui, *et al.* (1986), *The Development and Utilization of New Energy in China*, Energy Publishing House, Beijing, China.
4. *Proceedings of the First Solar Cooker Seminar, 1982*, Shanghai, China.
5. Introduction of solar cookers winning awards (1984), *Agriculture Engineering*, No. 3, p. 26.
6. The development and application of solar cooker in the countryside (1984), *Solar Energy Research and Application*, No. 1, p. 49, Lanzhou, China.
7. Photo album of solar cookers exhibited at the *First Exposition of Solar Cookers*, 1983, Beijing.
8. Hu Chengchun, *et al.* (1980), *The Utilization of Solar Energy in China*, Energy Publishing House, Beijing, China.