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Studies on Pan Cooking of Indian Bivoltine Cocoons

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Abstract

In India, most of the cocoons are cooked using an open pan cooking device and the cooking method is mainly applied for float reeling. Three-pan cooking method for half-sunk reeling and automatic cooking method for sunk reeling have already been introduced but these methods are not being applied widely. In order to obtain high quality raw silk from bivoltine hybrid cocoons, it is necessary to develop a simple cocoon cooking method for sunk reeling. An attempt was made in this study to develop a cocoon cooking method using 2 pans for sunk reeling. The samples consisted of KS×NB_4D_2 bivoltine hybrid cocoons. First, the temperature distribution inside the cocoon cooking pan was determined by using a thermometer. It was shown that the highest temperature that could be used was 96°C for this pan cooking device and it was also observed that there was a 3 or 4°C difference in the vertical distribution of the water temperature between the top and bottom portions of the pan. Second, the cocoons cooked after changes in the temperature and time were reeled. Based on the values of brushing waste weight, thickness of the dropped cocoons and number of reeled cocoons, the cocoon cooking degree was evaluated. Then, the 2-pan cocoon cooking method was proposed. Third, the 2-pan cocoon cooking method was compared to the 3-pan and the automatic cocoon cooking methods based on reeling results. When the 2-pan cooking method was used, reelability and nonbreakable filament length were superior to those of the other two methods. On the other hand, brushing waste weight was larger and raw silk percentage was lower than those of the other two methods. Although the 2-pan cocoon cooking method may lead to over-cooking, it could be used for simple sunk reeling.

Discipline: Sericulture
Additional key words: multi-ends reeling pan cooking, raw silk

Introduction

At present, in India the production of cocoons consists almost completely of multi × bivoltine cocoons and fewer bivoltine hybrids are produced. Cocoon cooking employing the pan method has been practiced for many years for the multi × bivoltine cocoons in the Indian silk industry and the float reeling method tends to prevail although the temperature distribution in the pan has not been fully studied. For reeling, there are various types of machines including charaka, cottage basin and multi-ends reeling machine, and multi × bivoltine raw silk is being produced by using these devices. The raw silk produced from multi × bivoltine cocoons, however, shows a low cohesion, high size deviation, and many winding breaks. Therefore a cooking and reeling technology should be developed to produce high quality raw silk.

The Bivoltine Sericulture Technology Development Project between Japan and India is being implemented to develop practical methods required for bivoltine sericulture under Indian conditions and to contribute to the promotion of the sericultural industry in India.

To produce high quality raw silk from the bivoltine hybrid cocoons, the 3-pan cooking method for half-sunk reeling has recently been introduced to multi-ends reeling machines. However, it is considered that a cooking method for sunk reeling should be developed. To apply a simple 2-pan cocoon cooking method for sunk reeling, attempts were made in this study to test the cooking procedure with 2 pans using the 3-pan cocoon cooking device. On the other hand, an automatic cocoon cooking machine was developed at CSTRI several years ago. It is difficult to determine which cocoon cooking method is suitable for Indian bivoltine cocoons. Therefore, a comparative study on cocoon cooking methods, 3-pan, 2-pan and automatic machine was carried out based on the results obtained when the same lot of cocoons was reeled after cooking using the three methods.

Materials and methods

1) Experimental cocoons

The experimental cocoons consisted of a KS × NB_4D_2 bivoltine hybrid race, which was reared during October 1993 by a sericulturist in Bidargupee village, Karnataka State, India. A part of the rearing results is depicted in Table 1.

2) Physical properties of the cocoon filament

To analyze the characteristics of the cocoon filament, the cocoons were cooked using 1 pan and the physical properties of the cocoon filament were determined as follows[1]. First, 10 cocoons were immersed into water at about 80°C which was heated to the boiling temperature for about 5 min and allowed to stand for about 5 min. Water at room temperature was sprinkled into the pan slowly to reach a temperature of less than 80°C. The cocoons were taken out for reeling. Thereafter the filaments were removed slowly from the cocoon and reeled in a sizing reel frame without kennel system. The cocoon filament size curve was obtained by weighing the sizing skein with a balance. Strength elongation curve was drawn using Tensilon UTM-II-20 in an atmosphere at 20°C and 65% relative humidity. Sample length was 10 cm, elongation speed was 100%/min. Young modulus, breaking strength and elongation were calculated from the curves.

3) Structure of the pan

Pan cocoon cooking was carried out using 1 pan out of the 3-pan cocoon cooking device. The lateral view of the structure of the cooking pan is shown in Fig. 1. The body of the pan is made of steel, the shape is round and the pan consists actually of two parts with a similar configuration. In the inner part there are 57 holes with a diameter of 1 cm each. The steam is discharged directly through a pipe at the bottom between the two parts. The steam that penetrates into the inner part through the holes induces the increase of the water temperature. The volume of water in the pan required during cooking was about 11 l.

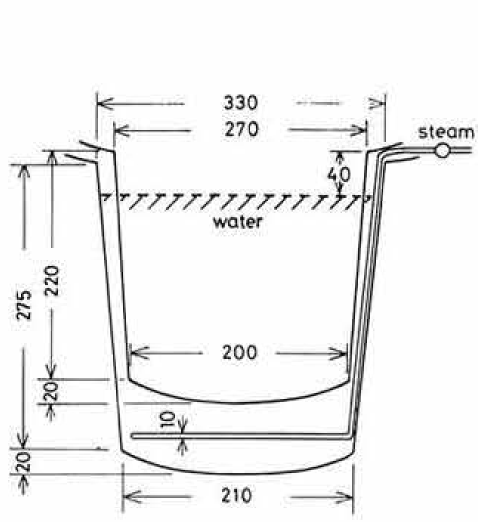

Fig. 1. Lateral view of pan

4) Cocoon cooking methods

(1) 3-pan cocoon cooking method: The 3-pan cocoon cooking method has been introduced to the Indian institute. This cooking method is suitable for half-sunk reeling. The cooking procedure is shown in Fig. 2.

(2) 2-pan cocoon cooking method: Two-pan cocoon cooking experiment for sunk reeling was conducted as described below by using 2 pans from the 3-pan cooking device depicted in Fig. 3. At first, 55 cocoons were put in the cooking basket, then the basket was immersed in hot water (96°C) for 30 s, and transferred to a water pan (60°C) and allowed to stand for 2 min. The basket was immersed in the 96°C hot water pan again. Here, the immersion time in the hot water pan (at 96°C) ranged from 5 to 9 min. Thereafter, the steam supply was discontinued and the basket was allowed to stand.

Table 1. Characteristics of KS × NB_4D_2 cocoons

Cocoon weight (g)	Cocoon shell weight (cg)	Cocoon shell percentage (%)	Dried cocoons (%)	Eliminated cocoons (%)
1.47	32.1	21.9	46	27

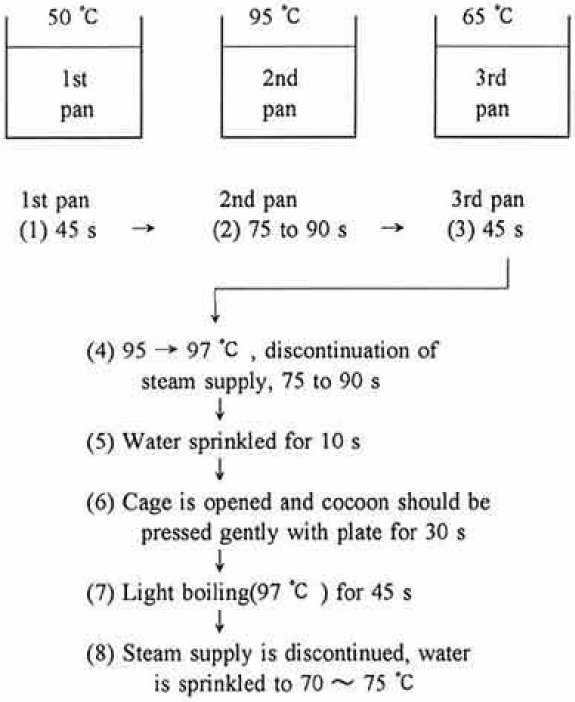

Fig. 2. 3-pan cocoon cooking procedure for half-sunk reeling

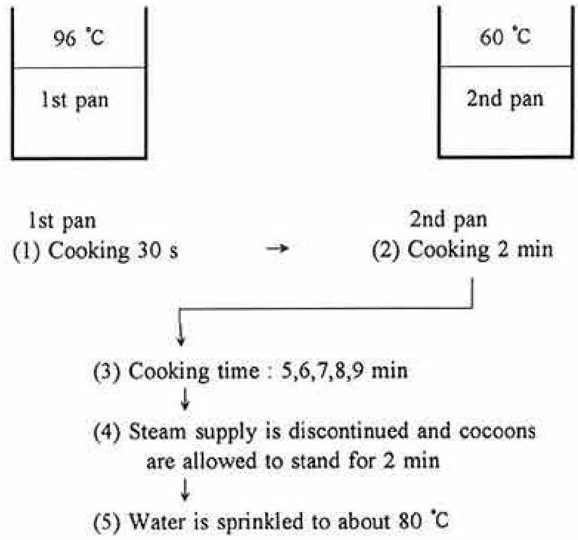

Fig. 3. 2-pan cocoon cooking experimental procedure using 3-pan cooking

Then water at room temperature was slowly sprinkled in the pan and the temperature was brought to about 80°C. By the above procedure, the cooking was completed and the cocoons were taken out for reeling.

(3) Automatic cocoon cooking method: For automatic cocoon cooking, a machine (V-shape, HM Type, Shinmasuzawa Kogyo Co., Ltd.) was used at CSTRI. The cooking conditions are indicated in Table 2.

5) Reeling

The Masuzawa multi-ends reeling machine was used for reeling. The reeling was set up for 8 cocoons, brushing temperature was 40°C, reeling speed was 160 m/min. Brushing was performed only once

Table 2. Cocoon cooking conditions for the automatic cooking machine

Parameters	Value
Cooking time	14 min
Soaking (front)	60°C
(rear)	70°C
Steaming	93–94°C
Permeation	80°C
Steam cooking	97–98°C
Finishing first	96°C

for experiments 2-2), 2-6) and 2-7). Cocoons that dropped during reeling were brushed again for experiment 2-8).

6) Cocoon cooking degree

After brushing of the cocoons once, reeling was carried out and measurements were performed as follows. The brushing waste weight (a), shell weight of dropped cocoons (b) and raw silk weight (c) were measured after keeping them for 1 day in a room at a temperature of 27°C and 65% R.H. Then the brushing waste weight (BW) was calculated:

$$BW\ (\%) = a/(a+b+c) \times 100.$$

Thereafter, the thickness of the dropped cocoons was measured, the thickness was divided into 50 μ classes (0–50, 51–100, · · ·, 501–550, · · ·) and the number of cocoons in each class was counted separately. Based on these values, the cocoon cooking degree was evaluated.

7) Frequency distribution of cocoon shell thickness

The objective is to describe the measurements performed in undercooked cocoons. Frequency distribution of cocoon shell thickness without reeling in cocoons cooked at 96°C for 5 min was determined. The results are shown in Fig. 4. The cocoon shell thickness averaged 562 μ. Secondly, 94, 95 and 96°C temperatures for cocoon cooking were changed 8 times each. As a result, cooking was performed 24 times. After cooking, the cocoons were reeled and

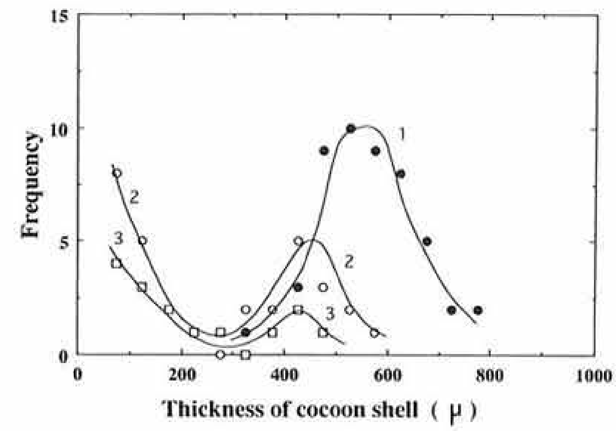

Fig. 4. Frequency of the thickness of cocoon shell
1: Cooking at 95°C, 5 min only,
2: Cooking at 92°C, 6 min, one brushing, then reeling,
3: Cooking at 96°C, 8 min, one brushing, then reeling.

the shell thickness of dropped cocoons was measured. Most of the cocoons were under-cooked at 94°C. At 95°C, some were well-cooked but most of them were under-cooked. At 96°C, cocoons were under-cooked, well-cooked or over-cooked. The characteristics of these cooked cocoons are shown in Fig. 4. Frequency distribution of the cocoon shell thickness at 92°C for 6 min with undercooking revealed a high frequency of values below 200 and in the range of 300 to 550 μ. Cocoon cooking at 96°C for 8 min was deemed preferable. Frequency of 400–450 μ thickness for the cocoon shell had decreased to half, compared to cooking at 92°C for 6 min.

As mentioned above, it is considered that the drop of the cocoons from the inner layer was related to under-cooking. Therefore as shown in Fig. 4, the number of cocoons with a shell thickness below 250 μ was counted. When the cocoon shell thickness was 50 μ and below, these thin-layered cocoons were counted as fully reeled cocoons.

8) *Comparative study on cocoon cooking methods for KS × NB_4D_2 cocoons*

The 3-pan and the automatic cocoon cooking methods were described. The 2-pan cocoon cooking method was outlined above. Comparative study on these cocoon cooking methods for KS × NB_4D_2 was carried out and the methods were evaluated based on the reeling values which were obtained by applying the calculation method for multi-ends reeling[4].

Results and discussion

1) *Physical properties of the cocoon filament*

The physical properties of the cocoon filament are shown in Fig. 5. From the outer layer to the inner layer, the Young modulus increased while the elongation and the filament size decreased. When about 80% of the whole cocoon filament was spun, the values of the Young modulus and the strength decreased. In most of the cocoon filaments the inner layer is prone to breaking, presumably due to the decrease of the spinning speed[5]. The changes in the pattern of the values from the outer layer to the inner layer were similar to those observed for the silkworm, *Bombyx mori*[2,5].

2) *Distribution of temperature in the pan*

The temperature distribution in each portion

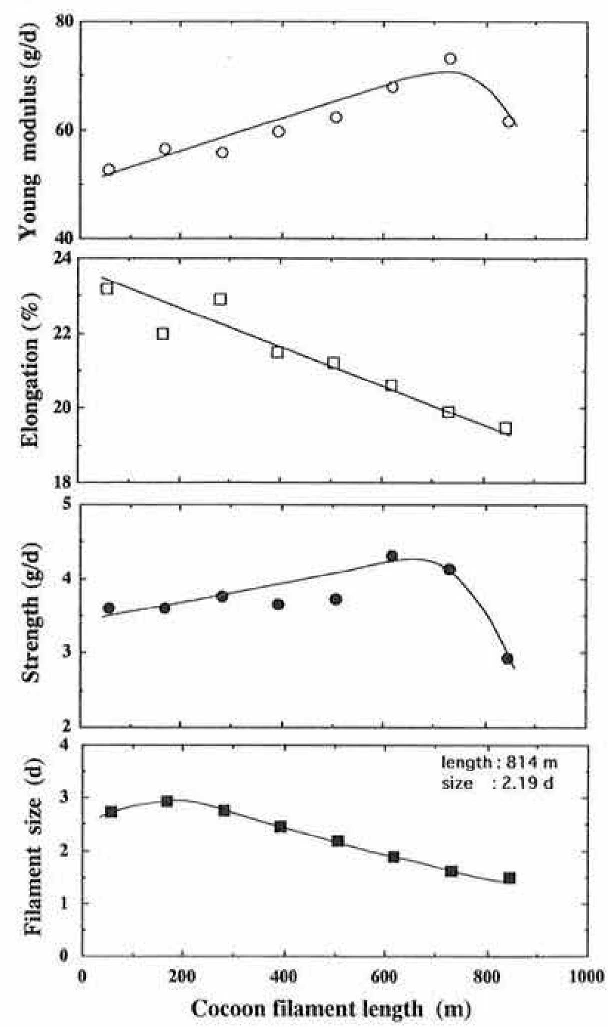

Fig. 5. Physical properties of the cocoon filament of KS × NB_4D_2

inside the pan was measured, when the temperature of the water at the surface was raised to 90 or 93°C. The results are shown in Fig. 6. The boiling conditions of water in Fig. 6-A were characterized by light boiling. As indicated in Fig. 6-B, boiling was strong. Regarding the horizontal distribution of the temperature, the temperature of the central portion was slightly lower than that of the outer part. As for the vertical distribution of the temperature, the difference in the temperatures between the top portion and bottom portion was 4°C (A) and 3°C (B), respectively.

When the temperature was above 96°C, the measurement was not possible. Since boiling was strong, the discharge of steam into the pan was dangerous and it was difficult to control the temperature at the water surface. Because the elevation of the area where CSTRI is located is high, the highest boiling temperature was 98°C. Based on the results shown in Fig. 6, the difference in the temperature between the top and bottom portions in the pan is the major aspect which should be considered. In general a cooking temperature in the range of 98 to 100°C is necessary for bivoltine cocoons. When the temperature is about 95°C, even with a difference of 1°C, the sericin solubility in the cocoon filament shows considable variations[3]. As a result, cocoon cooking is likely to be different. Accordingly, when this type of pan is used, it is necessary to determine the depth of the pan at which the cooking should be performed.

3) 2-pan cocoon cooking

The purpose is to analyze the cooking method for Indian bivoltine cocoons. The method consists of simple 2-pan cocoon cooking for sunk reeling. The cocoon cooking method is almost the same for both pan cocoon cooking and automatic cocoon cooking, basically. The cocoon sericin should be softened and swelling should be uniform. Cocoon cooking temperatures ranging from 98 to 100°C are convenient for cooking. However, in the previous experiment, it was shown that in open pan cooking, the temperature limit was 96°C. Consequently, it is necessary to determine a suitable cooking temperature and time, for Indian bivoltine cocoons, if the cocoon is to be cooked in hot water at 96°C. Although the degree of cocoon cooking can be estimated by visual inspection or by handling, more detailed information could be obtained if actual reeling were performed. Therefore the cocoons cooked by changing the temperature and time were reeled. Based on the values of brushing waste weight, thickness of the cocoons which dropped during the reeling operation and number of reeled cocoons, the cocoon cooking degree for the 2-pan cooking method was evaluated as follows (Fig. 7).

First, when the cocoon cooking time increased, the brushing waste weight increased as shown in Fig. 7. It is considered that the cooking time should be 6 min or below. Secondly, based on the frequency of the thickness of the inner side of the cocoon shell of dropped cocoons, it was found that the cooking time should be 7 min and above. Thirdly, it was observed that the number of reeled cocoons became more or less constant, if the cooking time was 7 min and above. Based on the results of the experiment depicted in Fig. 3, it is considered that the cooking time should be 6-7 min and it was eventually fixed at 6.0 min.

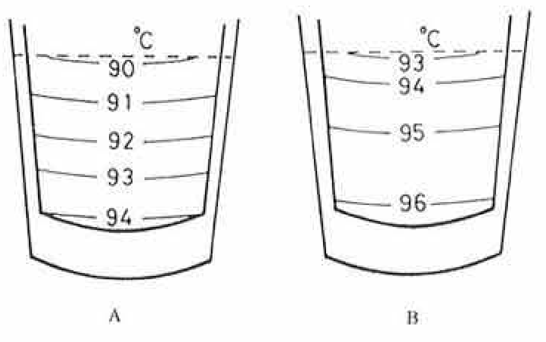

Fig. 6. Temperature distribution in a pan
A: Light boiling,
B: Strong boiling.

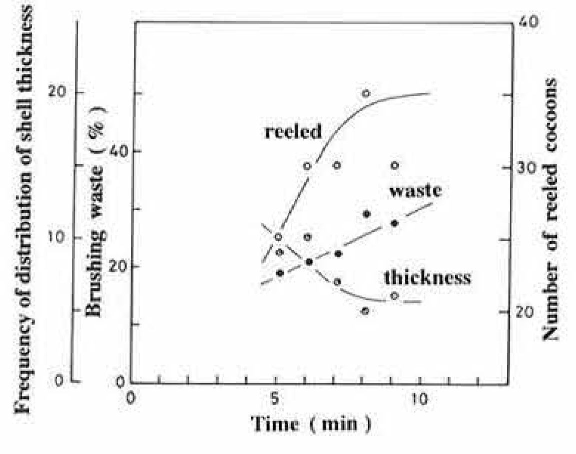

Fig. 7. Effect of cooking time on number of reeled cocoons, brushing waste and frequency of cocoon shell thickness ($0 \sim 50\ \mu$)
The cooking time showed in Fig. 3(3) was changed.

Table 3. Comparison of cocoon quality based on reeling among 3 cocoon cooking methods

Parameters	2-pan	3-pan	Automatic
Filament length (m)	782	827	770
Cocoon filament weight (g)	0.20	0.22	0.22
Filament size (d)	2.28	2.42	2.53
Raw silk (%)	13.7	15.6	15.0
Reelability (%)	84	74	78
Non-broken filament length (m)	657	612	601
Cooking and brushing waste on raw silk (%)	19.9	17.0	17.8

4) Comparative study on cocoon cooking methods for $KS \times NB_4D_2$ cocoons

The results of reeling of $KS \times NB_4D_2$ cocoons are shown in Table 3. The values of the filament length and size were similar to those indicated in Fig. 5. It also appears that the results were similar in the case of 3-pan cooking and automatic cooking, but were slightly different for the 2-pan cooking method, particularly, the rate of raw silk was 2% lower in the 2-pan cooking method than in the other two methods. Based on the larger brushing waste weight and the small filament size in the 2-pan cooking method, it is considered that the cocoons were slightly over-cooked. However, it was interesting to note that the reelability in the 2-pan cooking method was high compared to that of the other two methods. Accordingly, the non-broken filament was also longer than in the other two methods. In conclusion, the 2-pan cocoon cooking method may be suitable for sunk reeling.

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