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An Experimental Study on Reeling of Mulberry Silk Yarn

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Abstract*: In mulberry silk, apart from the quality of raw materials i.e., silkworm cocoon, the production of raw silk quality yarn is greatly influenced by the reeling process that includes type of contrivance along with several other factors. An attempt has been made in this study to get an idea on the combining effect of machine, material and process technology. When all these features combine well, production of a quality output is imminent. The present study aims at finding out the interactive effects of several factors like machine, material and process parameters of cocoon reeling of different mulberry cocoons Bombyx mori L. Added weightage has been given on two factors namely cocoon races and machine or contrivance types. The effects of these two variables on the physical, mechanical and tensile traits of raw silk filament have been recorded and analysed by using analysis of variance. The lead of this study indicated that cocoon variety and reeling contrivance have positive impact on many of the physical and mechanical attribute of raw silk filament.*

Key words*: Denier, NBFL, Mulberry silk, Charkha, Cottage Basin, Semi Automatic Reeling, Reelability, Cohesion*

I. Introduction

Silk is something that can add extra bit of elegance and spark to any attire, whether traditional Indian or western. Sericulture is a subject of combined science with an art of rearing silkworm for the production of cocoons and unravelling of the filament from that cocoon surface onto a suitable package. Around the globe, India is the solitary country producing commercially available all four varieties of silk viz., mulberry, tasar, muga and eri. Since silk fibre is a continuous filament & acquires an adhesive protein component as a natural gift for its protection & strength, normally it does not require any sort of complicated mechanism for its unravelling process. During favourable climatic condition about 80-85% raw silk can be recovered from a cocoon shell. Some inherent characteristics lie with the race itself and more importantly the selection of improper machineries that mismatches the quality of cocoons are the major causes of inferiority of raw silk fibre. These are the reasons, the quality of cocoons, yarns and fabrics in India are yet to reach the International standard because of many inter-linked problems associated with cottage based industry. The process of unwinding of filament from the cocoon surface by means of suitable contrivances is known as silk reeling. Here several filaments are combined together to form a single strand. This is achieved by unwinding filaments collectively from a group of cooked cocoons at one end in a warm water bath and winding the resultant thread onto a fast moving reel. However, this unravelling process is of immense importance which decides the quality of resultant raw silk thread. In turn, cocoon quality and choice of reeling contrivances play a substantial role in achieving the graded raw silk. In West Bengal, though many new mulberry varieties and silkworm genotypes have been developed, unfortunately the overall scenario has not changed significantly because of absence of proper post cocoon technological infrastructure. More importantly, the adoption of wrong technique without any process control measures, absence of quality concept and lack of awareness are considered to be the major impediments for de-acceleration in the growth of the industry. Various researchers have carried out work [1-3, 6] on reeling but little attention has been paid to the influence of cocoon variety and contrivance on properties of mulberry silk yarn after reeling operation with statistical feasibility.

II. Materials and Methods

In this experimentation, three different varieties of cocoons were chosen for running through three different reeling contrivances. The intention behind choosing such variables was to have interactive features between material and machine. Out of these nine combinations, an effort was given to identify the best and right combination of material and machine that would produce the best quality reeled silk yarn in terms of physical, mechanical and tensile properties. The cocoon varieties selected for the present study were Multivoltine x Multivoltine (MxM), Multivoltine x Bivoltine (MxBi), Bivoltine x Bivoltine (BixBi). Multivoltine cocoons are those which are available in multiple numbers of crops, have shorter filament length and said to be the inferior

amongst all varieties. Bivoltine cocoons are available in only two crops, have longer filament length and known to be the superior most amongst the varieties. Multivoltine x Bivoltine cocoons are produced as a hybrid of multivoltine and bivoltine silkworm races where the former contributes as a female component and the later as a male component which have moderate & intermittent characteristics. The contrivances used in this study are Charka, an indigenous crude appliance [CH], Improved Cottage Basin reeling machine [ICB], a machine with intermittent technology and Semi-Automatic Reeling Machine [SARM], a contrivance with superior technology.

The abbreviated codes of the cocoon varieties selected for the present study are:

- Multivoltine X Multivoltine (MxMi), the cocoon with traditional features
- Multivoltine X Bivoltine (MxBi), the cocoon with intermittent features
- Bivoltine X Bivoltine (Bi xBi), the cocoon with superior features

300 gms of dry cocoon were randomly chosen from each variety [Fig 1 (a), (b), (c)] and these were subsequently divided into 3 (three) groups for replicated results to obtain optimum accuracy. Each replication had 100 gms of 333333dry cocoons which were subjected for different treatments. Each cocoon variety was subjected to 3 different treatments and each treatment had three replications. Thus each cocoon type was subjected to different treatments for 9 observations. Various properties of silk are assessed in the current analysis – AFL, ANFBL, Renditta, Raw Silk %, Raw silk recovery, Reelability, Neatness, Evenness and some Tensile properties viz., Tenacity, Elongation were also measured. Cohesion was assessed using Duplan Cohesion Tester In addition, winding breaks/Skein/hour was also measured for each experiment and replication.

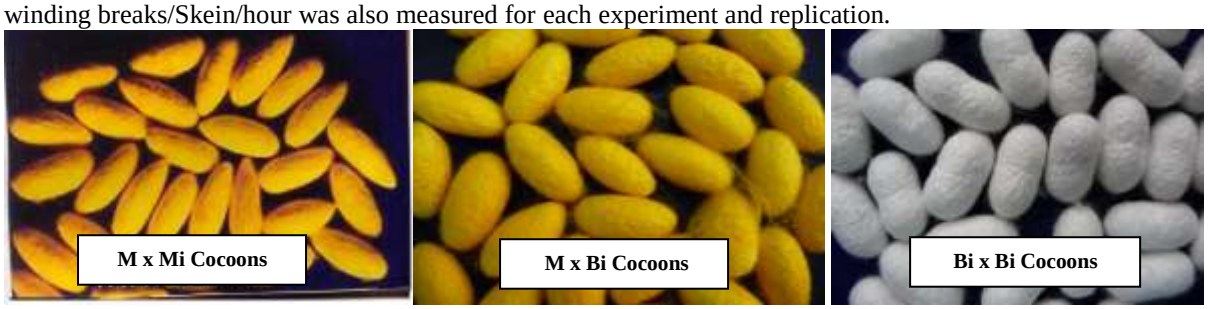

Fig. 1 :Cocoon race: (a) Multivoltine X Multivoltine (b) Multivoltine X Bivoltine (c) Bivoltine X Bivoltine

Single Cocoon reeling parameters namely Filament Length and filament weight was measured by using Epprouvette and Digital Weighing Balance respectively in each replication. Average Filament Length (AFL) and Average Non-Breakable Filament Length (ANBFL) have been measured. Denier of the single filament was also measured as per formula given below:

$$Denier = [Weight\ of\ silk\ filament\ (g) \div Length\ of\ silk\ filament\ (m)]\ X\ 9000$$

In each case other than the crude appliance Charkha (CH), the dried cocoons were subjected to boiling at about 100^0C (known as cooking) for 3 – 5 minutes for softening of sericin protein present in the cocoon filament to facilitate easy unravelling of filament from the cocoon surface to the fast moving reel of comparatively small diameter. The reeling in these cases were done at comparatively lower temperature of 50^0 – 60^0C.Separate Re-Reeling were done to transfer the yarn in a standard size hank (150 cm.) In charkha reeling, cooking and reeling were done simultaneously at a high temperature (100^0C) to directly form a large standard size hank. No separate Re-reeling is done in this process.

III. Results and Discussions

Quality of cocoons, reeled yarn and fabrics manufactured in India is still not up to the acceptable international standard because of many shortcomings in the sericulture practices as well as post reeling operations. The objective of this study is to optimise a combination of material and machine for producing premium quality of mulberry reeled silk yarn with available options. The results in this experimentation have been summarised in tables 1 to 3.

Table 1: Cocoon characteristics of different races

Cocoon race	Multivoltine x Multivoltine	Multivoltine x Bivoltine	Bivoltine x Bivoltine
Average filament length, mt	408	617	680
ANBFL, metre	249	583	607
Denier & Range	2.23 (2.01-2.38)	2.57 (2.42-2.75)	2.12 (2.01-2.29)

Table 2: Influence of reeling devices on qualitative characteristies of cocoons of different races

Cocoon race	Multivoltine x Multivoltine M x Mi			Multivoltine x Bivoltine (M x Bi)			Bivoltine x Bivoltine (Bi x Bi)		
Physical properties	Reeling device			Reeling device			Reeling device		
	CH	CB	SARM	CH	CB	SARM	CH	CB	SARM
Renditta	10.16	13.48	14.37	10.92	8.98	8.89	8.46	10.27	10.38

Raw silk %	9.85	7.42	6.95	11.25	11.14	9.15	11.83	9.62	9.74
Raw silk recovery (%)	78	72	66	86	84	81	82	80	76
Reelability (%)	84	75	74	94	94	86	88	91	92
Neatness (%)	65	70	77	87	86	89	84	87	90
Evenness (%)	75	83	70	91	92	95	89	91	95

Table 3: Influence of reeling devices on tensile properties of cocoons of different races

Tensile properties	**Multivoltine x Multivoltine (M x Mi)**			**Multivoltine x Bivoltine (M x Bi)**			**Bivoltine x Bivoltine (Bi x Bi)**		
	Reeling device			**Reeling device**			**Reeling device**		
	CH	**CB**	**SARM**	**CH**	**CB**	**SARM**	**CH**	**CB**	**SARM**
Cohesion	129	95	60	89	93	70	79	102	85
Peak load, cN	89.02	88.88	81.29	65.31	82.50	71.80	63.44	64.40	64.19
Breaking elongation (%)	15.50	14.29	14.06	15.30	16.23	12.71	11.34	12.15	11.99
Tenacity, cN/tex	4.56	4.18	4.13	2.76	3.55	3.19	3.62	3.48	3.39
Winding breaks/skein/hr	14	08	01	04	01	01	01	06	01

From the accompanying table 2 and fig 4, it is observed that the average value of renditta is minimum with charkha followed by cottage basin and semi-automatic reeling machine respectively (in case of M X Mi as well as for Bi x Bi race). For M x Bi race, the situation is reversed. Further it is evident that charkha system of reeling shows higher raw silk percentage, reelability % (fig 2) and raw silk recovery % (fig 3) in comparison to other two sets of machines. Bivoltine race of mulberry silk is associated with less deviation in its fineness (table 1). Neatness and evenness parameters for M x Mi race are lowest for charkha reeling device. It means that the charkha reeling device is unable to produce evener yarn in comparison to other two contrivances. This may be attributed to racial character and irregularities contributed by the machine. Semi-automatic reeling machine is able to produce the present variety with improved neatness and evenness but with lower quantitative output. Similar trend is observed in case of tensile characteristics (table 3) which are improved when multivoltine cocoons are processed and reeled in charkha reeling device. Cohesion (number of strokes), tenacity and breaking elongation are influenced and found to be maximum for charka reeling device.

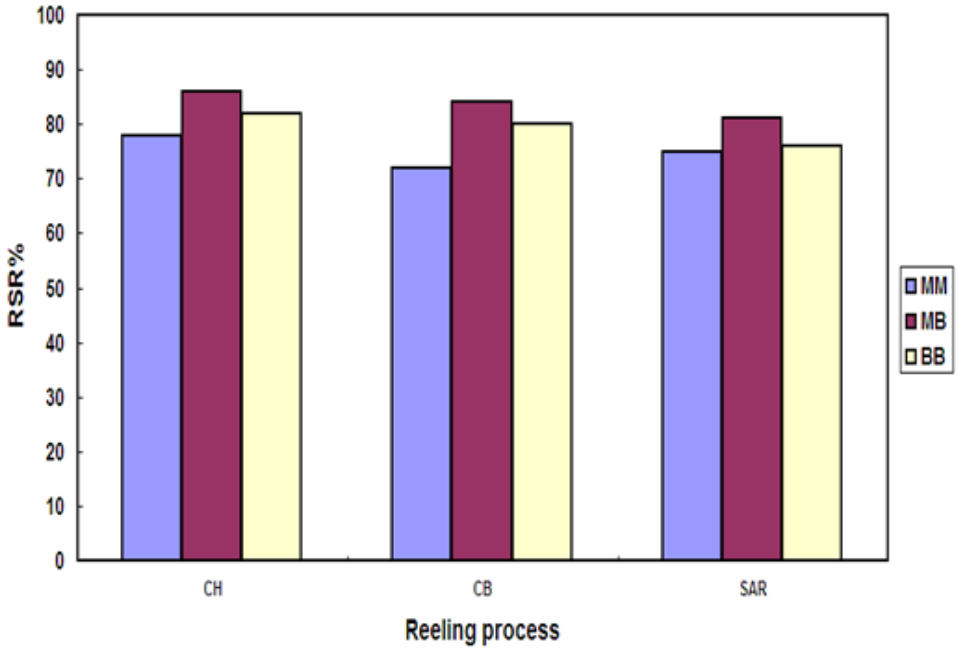

Figure 2: Effect of cocoon type and reeling process on Raw Silk Recovery %

However this device is also associated with highest number of winding breaks for multivoltine (M x Mi) variety of cocoon. Reeling of silk filament produces maximum breaking elongation on all three devices with multi x multi race of cocoon with Charkha system yielding the highest elongation. This result is not in line with the original values of tenacity but coincides with the expected outcome. Experimentation with this variety of cocoon yields the same trend of result indicating that qualitative as well as tensile characteristics are distinctly improved. Raw silk%, reelability as well as raw silk recovery was considerably higher for this race of cocoon reeled on charkha reeling device. However these positive improvements are found to be less offset with the deterioration in neatness and evenness of the silk yarn when reeled on charkha device.

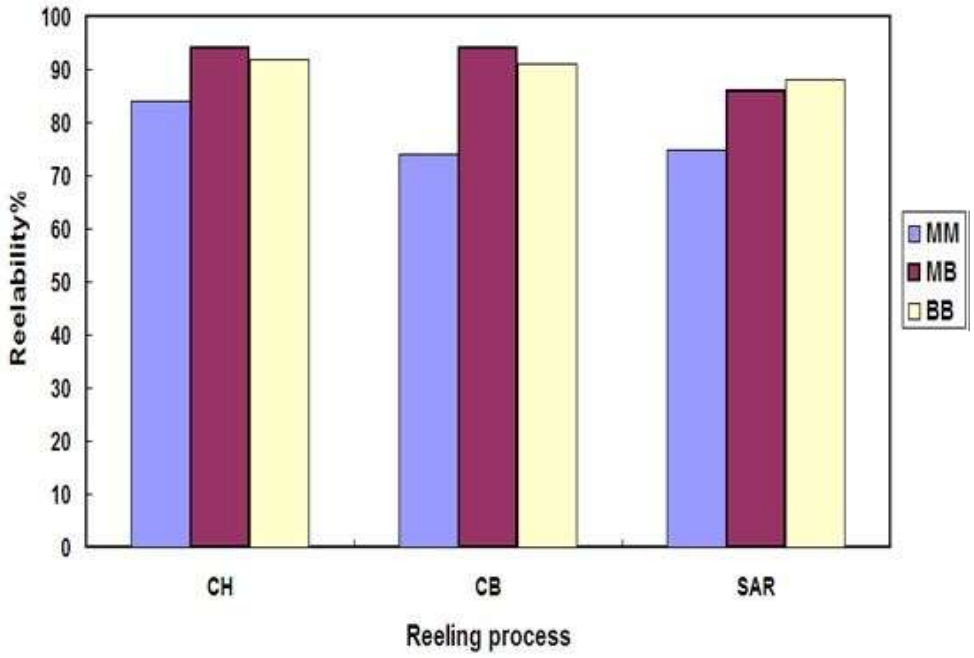

Figure 3: Effect of cocoon type and reeling process on Reelabilty %

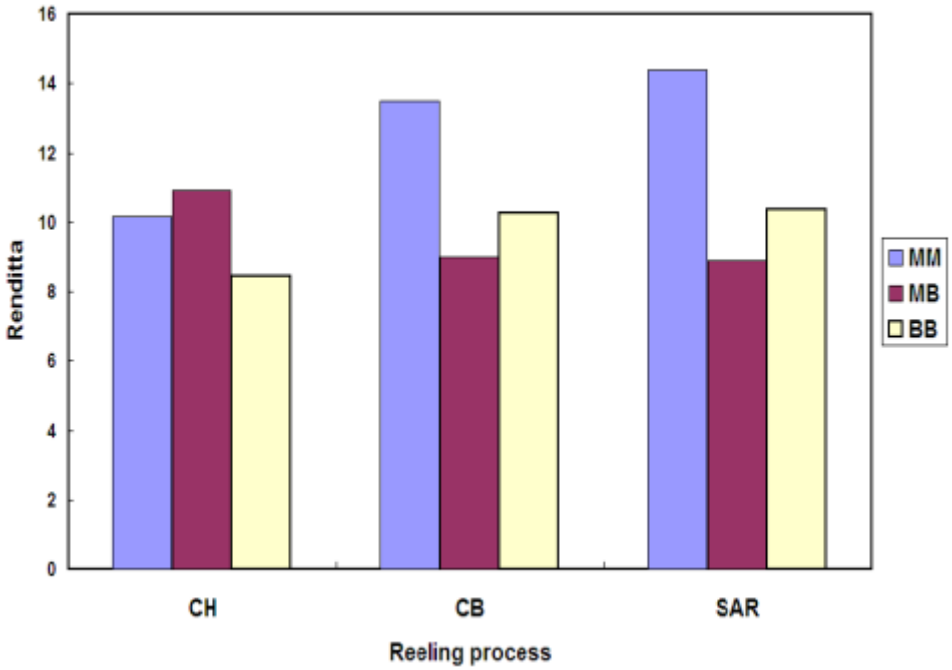

Figure 4: Effect of cocoon race and reeling process on Renditta

Table 4: ANOVA results for physical and tensile properties of reeled silk yarn

Factor		RSR %	Reelability	Renditta	Neatness
F-value	Cocoon type (A) Contrivance or device (B)	**331.34** **132.33**	**18.66** 4.93	**9.08** **11.64**	**15.71** 1.75
Status of significance	Cocoon type (A) Contrivance or device (B)	S**(**)**; S **(*)** S **(**)**; S **(*)**	S **(**)**; S **(*)** **I**	S **(*)** S **(*)**	S **(*)** I
Factor		Cohesion	Tenacity	Elongation	Winding breaks
F-value	Cocoon type (A) Contrivance or device (B)	0.14 2.08	**14.58** 1.28	0.97 4.58	1.88 1.51
Status of significance	Cocoon type (A) Contrivance or device (B)	I I	**S (*)** I	I I	I I
$F_{(2,4)}$: 18.00 (at 1% ******) , 6.94 (at 5% *****) S = Significant, I = Insignificant					

Statistical Analysis: Data collected from all experiments with three replicates each were subjected to statistical analysis (table 4). Two way Analysis of Variance (ANOVA) was carried out to find out the significant differences between the varieties and reeling processes. Multiple Comparison of means were made depending on F-ratio and the critical difference (CD) values based on student t criteria at 5% and 1% level of significance

utilizing the standard statistical package. It is observed that the influence of cocoon race or type on Raw silk recovery % (RSR) is highly significant both at 1% and 5% level while effect of cocoon race and contrivance on Renditta is significant at only 5% level. Reelability (%) Neatness and tenacity are also significantly influenced (significant at 5% level) by the cocoon race or type.

IV. Conclusions

Production process of any textile does not give emphasis either on quality or on quantity in isolation. A single factor independently may certainly have influence on the production process but more importantly the orchestration of several factors in combination have more crucial role in carrying out the process unto the production of the end product.[6] But machine quality and more importantly the process technique too have consequential effects on the same. It is very difficult to find out the percent apportionment of the influential factors, but obviously the combinations of all factors give a visible material output. The present study was aimed at finding out the interactive features of machine and material with standard process parameters on reeling characteristics of mulberry cocoons *Bombyx mori* L.

The present course of experiments with reeling of silk filament leads to following Inferences:

- Minimum renditta is achieved with Bi X Bi race on Charkha reeling machine. It can reel silk cocoons with highest raw silk percentage, highest raw silk recovery percentage and maximum reelability for all three varieties of cocoon. Charkha reeling produces maximum reelability with Multivoltine x Bivolltine cocoon race.
- Maximum tenacity is achieved for silk filaments from Multivoltine x Bivoltine (M x Bi) variety on Charkha reeling device. Filaments reeled from Multi x Multi cocoon registers highest tenacity for all the three devices and hence prove to be strongest variety. Bi x Bi race produces silk filament stronger than Multi x Bi type when reeled on all the three machines.
- On all three devices, reeling of silk filament produces maximum breaking elongation with Multi x multi race of cocoon with Charkha system yielding the highest elongation. This result is not in line with the original values of tenacity but coincides with the expected outcome.
- Multi x multi cocoon race appears to prove its effectiveness with maximum cohesion when reeled on charkha reeling machine.
- Minimum winding breaks are observed with Bi x Bi race when reeled on the same device.
- Some prominent quality parameters as RSR%, renditta, reelability%, neatness and tenacity are significantly influenced by both cocoon race and contrivance.

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