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STUDIES ON EFFECT OF STORAGE PRACTICES OF MODAL & RAILY ECO RACE COCOONS ON REELING PARAMETERS AND YARN QUALITY

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ABSTRACT

Purpose of this study was to assess the change of single cocoon quality characteristics and reeling performance due to preservation for 6, 12 and 18 months in net cage after stifling and in cold storage without stifling. Reduction in cocoon weight observed significantly after stifling/hot air drying whereas non-significant drop was observed for shell weight. Average filament length remains at par between green, stifled and preserved (net cage up to 6 month and cold storage up to 18 months) varieties. Significant reduction of average filament length & non- broken filament length was observed for cocoons stored in net cage after stifling for 12- & 18-months due to high number of breaks during filament withdrawal. So, reelability deteriorates to the significant extent as estimated by reeling testing machine. No change in single filament denier of all varieties were observed. Reduction in raw silk recovery (%) and yield/1000 cocoons (g) for 12- and 18-months net cage preserved stifled cocoons were observed due to excessive breaks during reeling although no significant difference exists. For cocoons stored in cold storage without stifling up to 18 months other varieties, all these parameters are at par to green/stifled varieties. Study revealed that cold storage preservation can be opted for longer duration storage of cocoons.

Keywords: Deflossing, fibroin, non-broken, pelade, raw silk, reelability, sericin.

Introduction

Tropical tasar cocoons are produced by the silkworms *Antheraea mylitta Drury* species either twice (bi-voltine) or thrice (tri-voltine) in a year. The cocoons harvested during second crop (bi-voltine) or third crop (tri-voltine) are commonly used for commercial reeling purpose to produce yarns (Jolly *et al*., 1979). Since the high number of cocoons produced during this time, so it is very difficult to convert all the cocoons to yarn by reeling process within short period of time. Also, if the same cocoons were preserved in as it is condition, the moth will emerge as per weather conditions which will make it Un-reelable because of excessive breaks during yarn production. So, the cocoons need to be stifled at about 90^{o}C for 5 to 7 hours to dry pupae inside the cocoon completely so that emergence of moths can be prevented (Sonwalkar, 1993). After stifling, cocoons are preserved in net cage rack to avoid damages due to rat and ant after which stored cocoons can be taken for reeling when required in future. As per the information received from tasar silk producing clusters, reeling performance like reelability (%) and raw silk recovery (%) of cocoons deteriorate due to prolonged storage.

It was found that reelability (%) and raw silk recovery (%) of mulberry cocoons were significantly better when it is spun under low temperature and humidity as compared to high temperature & humidity. Also, the quality of yarn in terms of cleanness, neatness, breaking elongation and tenacity were found better in low temperature and humidity. The effect of humidity and temperature on reeling parameters and quality of yarn may be due to structural changes in sericin due to high humidity during spinning of cocoons (Naik & Somashekar, 2004; Naik & Somashekar, 2008 and Singh *et al*., 2011). Reelability

(%) depends on water content of cocoon which should be low in order to obtain good quality of raw silk and better performance with respect of reelability. Due to rapid drying of moisture from shell during cocoon spinning, the sericin remains in random coil structure (Akahane & Tsubouchi, 1994 and Zhu *et al.*, 1995). From the evaluation of absorption peak found by Fourier Transform Infrared spectroscopy for amide 1, 2 and 4 of sericin; it was observed that there will be difficulty in dissolution of β-structure. The formation of β-structure of sericin is due to higher humidity in atmosphere. Sericin I of structure like random coil absorbs moisture and that's why the intra molecular hydrogen bonds got snapped due to the presence of water molecules. So, the structure which was earlier folded becomes unfolded followed by shifting to β-structure which is difficult to dissolve. So, there will be reduction in solubility of sericin which affect the cooking efficiency as well as reeling performance of mulberry cocoons (Komatsu, 1980). When temperature as well as humidity will be at higher side, drying duration of liquid silk gets delayed. So, the sericin molecules present in solution will transform from random coil to β-structure which enhances the sericin crystallinity (Kataoka, 1977). This enhances the adhesive strength of sericin which results in less solubility during degumming (Tanaka *et al.*, 1980).

Preservation of tropical tasar cocoons in cold storage without hot air drying/stifling followed by net cage rack storage facility results at par reeling performance in comparison of green/harvested cocoons (Gahlot and Khan, 2015). It is also reported about descending trend of single cocoon quality as well as reeling performance of Daba BV eco-race after one year storage in net cage with stifling (Chattopadhyay *et al.*, 2022). Descending trend in reeling parameter like raw silk recovery (%) were observed with increase of storage duration of muga cocoons and about 15% reduction was observed after 6 months storage (Mishra *et al.*, 2020). No significant change in tenacity of yarn was observed by drying of tasar and muga cocoons between 80 to 140^{o}C apart from loss in moisture content as evaluated by x- ray diffraction and scanning electron microscopy assessment (Das, 2020). Formation of Eri cocoons is better when temperature and humidity remains between 25 to 30^{o}C and 60 to 75% respectively (Sarkar, 1988).

From the literature review, it is found that reeling performance of mulberry cocoons deteriorates due to prolonged storage after hot air drying/stifling. For Daba eco-race the study was conducted to assess the single cocoon quality and reeling performance after stifling and one year preservation. Also, from tasar silk sectors, information was received that raw silk recovery as well as productivity reduced for cocoons stifled and stored for longer period.

Hence, this study was performed for two Tropical tasar ecoraces namely Modal & Raily for assessment of the single cocoon quality &reeling performance of green, stifled/hot air dried as well as cocoons stored in net cage after stifling and in cold storage without stifling for 6, 12- and 18-months.

Materials & Methods

Materials

Green/harvested, stifled/hot air dried and stored for 6, 12 and 18 months in net cage after stifling and in cold storage without stifling tropical tasar Modal & Raily ecoraces cocoons were used in this study. Total 4000 Modal green cocoons were taken from Tasar Rearer Co-Operative Society, Bishoi, Keonjhar, Odisha, India and total 4000 Raily green cocoons were taken from Regional Sericulture Research Station, CTR&TI, CSB, Jagdalpur, C.G., India. Out of these, 500 green cocoons of each ecoraces were taken for assessment, and remaining 2000 cocoons were subjected to stifling process. Out of 2000 stifled cocoons, 500 cocoons were taken for testing and remaining 1500 numbers were preserved in net cage for 6, 12- and 18-months study. Also, remaining 1500 green cocoons without stifling were preserved in cold storage chamber at 4 to 6^{o}C to conduct similar experimental trial of 6, 12- and 18-months durations stored cocoons. The chemicals used in this trial was sodium bicarbonate ($NaHCO_3$) & sodium carbonate (Na_2CO_3) of laboratory grade from Merck Life Science Private Limited, Mumbai.

Methods

Stifling and storage of cocoons in net cage

Modal & Raily green tasar cocoons of 2000 nos each were stifled using laboratory hot air drier of 350-liter capacity, single phase 3 KW from M/s Hi-Tech Instrument, Chandigarh, India as per standard procedure (Jolly *et al.*, 1979 and Sonwalkar, 1993). Cocoons were put in hot air oven on the rack and after closing the door and exhaust entrance; temperature was increased and set at 90^{o}C which has been achieved in one hour. Same condition was maintained for another two hours. After that exhaust windows were opened and then same condition maintained for another three hours so that moisture and pupae fluid can be evaporated from drying chamber. After six hours of drying, the heater is turned off and air circulation was continued for another one hour so that temperature can be reduced to ambient condition. After that cocoons were taken out from drying chamber. Then Out of 2000 cocoons, 500 cocoons were taken for single cocoon characteristics and reeling performance assessment and remaining 1500 numbers were stored in net cage to avoid damage from rat & ant. Out of these 500 cocoons were evaluated after 6 months, 500 cocoons after 12 months and remaining 500 cocoons after 18 months period.

Storage of cocoons in cold storage

Total 1500 cocoons of each ecorace were stored in cold storage chamber at 4 to 6^{o}C temperature. Out of total 1500 cocoons, 500 cocoons were evaluated after 6 months, 500 cocoons after 12 months and remaining 500 cocoons after 18 months period for reeling performance and single cocoon characteristics.

Evaluation of cocoon and shell weight

Cocoon and shell weight for green, stifled and stored for 6, 12 and 18 months in net cage after stifling and in cold storage without stifling were carried out as per standard procedure (Sonwalkar, 1993). Firstly, cocoon weight was taken after removal of peduncle using precision electronic balance. After that the cocoons were cut down by stainless steel blade and pupa and other impurities removed from the shell. After removal, shell weight was measured using the balance. Total 50 observations were taken for each variety.

Softening of tasar cocoons

Cooking/softening of tasar cocoons were performed by following newly developed non-peroxide technique using sodium carbonate and sodium bi- carbonate (Khan *et al*., 2019). Total 90 cocoons were softened for each replication and five replications were carried out for each trial. About 3 liters water was taken for 90 cocoons with material to liquor ratio 1:30. Sodium carbonate and sodium bicarbonate of each 10 g/l was added to water and dissolved properly with proper stirring using glass rod. The cocoons were taken in nylon net cloth & immersed in solution which then boiled for 25-30 min without pressure. Then steaming were carried out for another 30-45 min keeping over same solution in pressure cooker. After cooking, the cocoons were taken out and subjected for deflossing to find out single end and perform single cocoon reeling as well as reeling performance assessment.

Single cocoon reeling assessment

After softening of tasar cocoons, filament was withdrawn from single cocoon under semi- moist condition by using a device “Epprouvette” and simultaneously breaks were noted. The total length of yarn from single cocoon was calculated from the number of revolutions noted from counter meter of Epprouvette multiplied by 1.125 m (circumference). Total 10 readings were taken for green, stifled and stored (both in net cage and cold storage chamber) cocoons for each replication and total five replications were performed. After drying in hot air dryer for 15 min at 105±3^{o}C (BS4784- 1973, 1974), yarn weight was noted using precision electronic balance and denier was calculated along with non- broken filament length (NBFL) using below expressions (Sonwalkar, 1993).

$$\text{Filament length(m)} = \text{Revolution in Epprouvette X } 1.125 \quad (a)$$

$$\text{Nonbroken filament length (NBFL) (m)} = \frac{\text{Total filament length (m)}}{\text{No. of cocoons} + \text{No. of breaks}} \quad (b)$$

$$\text{For single cocoon, NBFL (m)} = \frac{\text{Total filament length (m)}}{1 + \text{No. of breaks}} \quad (c)$$

$$\text{Yarn denier} = \frac{\text{Weight of yarn (g) x 9000}}{\text{Length of yarn (m)}} \quad (d)$$

Assessment of reeling performance

Reeling performance for each trial were performed using Motorized Reeling cum Twisting Machine (MRTM). The yarn withdrawal was carried out following dry reeling technique from semi- moist cocoons after softening with reeling speed of about 30 m/min. Breakages during yarn withdrawal were noted and 80 cocoons were used for each experimental trials and 5 replications were carried out. Yarns as well as wastes generated during reeling were dried using hot air drier at 105±3^{o}C (BS4784- 1973, 1974). The reelability (%), raw silk recovery (%) and yield/1000 cocoons (g) were estimated by following standard method and expressions (Sonwalkar, 1993).

$$\text{Reelability (\%)} = \frac{\text{No. of cocoons taken for reeling X 100}}{\text{No. of cocoons taken for reeling} + \text{No. of breaks during reeling}} \quad (a)$$

$$\text{Raw silk recovery (\%)} = \frac{\text{Yarn weight (g) x 100}}{\text{Yarn weight (g)} + \text{waste weight (g)}} \quad (b)$$

$$\text{Yield/ 1000 cocoons (g)} = \frac{\text{Yarn weight (g) x 1000}}{\text{No. of cocoons reeled}} \quad (c)$$

Conditioning of yarn samples

The yarn samples kept under standard atmospheric conditions that is 65±2% relative humidity and 27±2^{o}C temperature for 24 hours (ASTM D 1776/1776M-15, 2015).

Analysis of experimental data

The experimental data were analysed for single cocoon quality characteristics (cocoon & shell weight, filament length, non-broken filament length and filament denier) and reeling performance (reelability %, raw silk recovery % and yield/1000 cocoons g) using MS- Excel software.

Results and Discussion

Cocoon and shell weight

The cocoon and shell weight of Modal & Raily eco- races for green, stifled and preserved for 6,12 and 18 months in net cage after stifling and in cold storage without stifling are given in Table 1 & 2. Significant reduction (about 60%) of cocoon weight was found after stifling which is due to loss in moisture from cocoons shells and evaporation of body fluid from pupae. No significant difference found for shell weight between green, stifled and stored cocoons. Some reduction of shell weight was found after stifling which may be due to elimination of moisture from cocoons shell. The results are in line to the previous studies conducted for mulberry, tasar and Muga (Sonwalkar, 1993; Chattopadhyay *et al.*, 2022; Das, 2020; Khan *et al.*, 2019 and Mishra *et al.*, 2020).

Table 1: Cocoon and shell weight of Modal ecorace

Parameters	Type of cocoons							
	Green/ Harvested	Stifled/ Hot air dried	Preserved in net cage after stifling (months)			Preserved in cold storage without stifling (months)		
			6	12	18	6	12	18
Average Cocoon weight (g)	14.30	5.90	5.93	6.20	6.43	6.00	5.85	5.92
Standard deviation (g)	1.46	0.64	0.54	0.75	0.79	0.70	0.65	0.68
Coefficient of variance (CV) (%)	10.20	10.84	9.05	12.10	12.45	11.65	11.10	10.90
Confidence interval (CI) (±) (g)*	0.40	0.18	0.15	0.21	0.22	0.20	0.19	0.19
Average Shell weight (g)	2.61	2.40	2.41	2.55	2.45	2.35	2.32	2.52
Standard deviation (g)	0.54	0.50	0.53	0.65	0.69	0.50	0.60	0.64
Coefficient of variance (CV) (%)	20.75	21.00	21.90	25.50	23.40	21.20	25.90	24.45
Confidence interval (CI) (±) (g)*	0.15	0.14	0.15	0.18	0.19	0.14	0.17	0.18

*at 5% level of statistical confidence; No of observations: 50
Confidence interval (CI)= Std. dev. /$N^{0.5}$X 1.96

Table 2: Cocoon and shell weight of Raily eco ace

Parameters	Type of cocoons							
	Green/ Harvested	Stifled/ Hot air dried	Preserved in net cage after stifling (months)			Preserved in cold storage without stifling (months)		
			6	12	18	6	12	18
Average Cocoon weight (g)	15.50	6.13	6.20	6.60	6.40	5.95	6.20	6.15
Standard deviation (g)	1.25	0.44	0.60	0.80	0.78	0.60	0.75	0.69
Coefficient of variance (CV) (%)	8.10	7.18	9.70	12.10	11.90	10.10	12.10	11.98
Confidence interval (CI) (±) (g)*	0.35	0.12	0.20	0.22		0.17	0.21	
Average Shell weight (g)	2.75	2.61	2.72	2.85	2.82	2.53	2.65	2.74
Standard deviation (g)	0.48	0.44	0.48	0.55	0.62	0.60	0.58	0.57
Coefficient of variance (CV) (%)	17.50	16.71	17.65	19.30	18.20	23.70	21.90	19.45
Confidence interval (CI) (±) (g)*	0.13	0.12	0.13	0.15		0.17	0.16	

*at 5% level of statistical confidence;No of observations (N): 50
Confidence interval (CI) = Std.dev./$N^{0.5}$X 1.96

Single cocoon reeling characteristics

Filament length

Filament length for green, stifled and stored Modal as well as Raily cocoons both in net cage and cold storage are mentioned in Table 3 & 4. It was found from Table 3 & 4 that no change of filament length for Modal & Raily tasar cocoons after stifling/hot air drying and due to storage/preservation up to six months stored in net cage rack, and up to 18 months stored in cold storage. but there is some reduction in filament length observed in case of net cage stored stifled cocoons for 12 and 18 months.

The results are in accordance to the earlier studies conducted for Daba tasar cocoons (Chattopadhyay *et al.*, 2022).

Table 3: Filament length of Modal tasar cocoons

Type of cocoons	Filament length			
	Average (m)	Standard deviation (SD) (m)	Co- efficient of variance (CV) (%)	Confidence interval (CI)*
Green/Harvested	1291.20	232.40	18.00	64.40
Stifled/Hot air dried	1331.60	199.80	15.00	55.40
Preserved 6 months in net cage after stifling	1301.80	173.20	13.30	48.00
Preserved 12 months in net cage after stifling	1196.00	210.50	17.60	58.32
Preserved 18 months in net cage after stifling	1059.00	174.25	16.79	48.30
Preserved 6 months in cold storage without stifling	1355.60	215.20	15.87	59.70
Preserved 12 months in cold storage without stifling	1327.20	176.10	13.30	48.80
Preserved 18 months in cold storage without stifling	1289.54	174.56	14.23	48.39

*At 5% level of statistical confidence; No of observations (N): 50
Confidence interval (CI) = Std. dev. /$N^{0.5}$X 1.96

Table 4: Filament length of Raily tasar cocoons

Type of cocoons	Filament length			
	Average (m)	Standard deviation (SD) (m)	Co- efficient of variance (CV) (%)	Confidence interval (CI)*
Green/Harvested	1398.20	137.80	9.85	38.20
Stifled/Hot air dried	1375.81	134.61	9.78	37.30
Preserved 6 months in net cage after stifling	1400.50	180.00	12.90	49.90
Preserved 12 months in net cage after stifling	1270.50	190.50	15.00	52.80
Preserved 18 months in net cage after stifling	1180.25	165.20	12.45	45.80
Preserved 6 months in cold storage without stifling	1285.60	205.60	14.80	57.00
Preserved 12 months in cold storage without stifling	1410.70	195.50	13.90	54.20
Preserved 18 months in cold storage without stifling	1350.24	183.43	14.50	50.85

*at 5% level of statistical confidence ;No of observations **(N): 50**
Confidence interval (CI) = Std.dev./$N^{0.5}$X 1.96

Non- broken filament length (NBFL)

Non- broken filament length (NBFL) for green, stifled and stored cocoons is shown in Table 5 & 6, which depicts that for Modal as well as Raily tasar cocoons after 12- & 18-months storage in net cage after stifling exhibits significantly lower NBFL as compared to green and cold storage preserved cocoons. No difference was found between other cocoon varieties. The significant reduction of non- broken filament length is due to excessive breaks occurred during yarn withdrawal by Epprouvette even after softening as per standard procedures (Khan *et al.*, 2019). Similar finding also reported as per earlier research study conducted for mulberry and tasar Daba cocoons (Chattopadhyay *et al.*,2022; Sonwalkar, 1993; Khan *et al.*, 2019; Das, 2020 and Mishra *et al.*, 2020).

Table 5: Non- broken filament length (NBFL) of Modal tasar cocoons

Type of cocoons	Non- broken filament length (NBFL)			
	Average (m)	Standard deviation (SD) (m)	Co-efficient of variance (CV) (%)	Confidence interval (CI)*
Green/Harvested	118.30	53.00	44.80	14.70
Stifled/Hot air dried	98.80	21.50	21.80	5.96
Preserved 6 months in net cage after stifling	100.20	9.90	9.90	2.75
Preserved 12 months in net cage after stifling	82.50	17.50	21.20	4.85
Preserved 18 months in net cage after stifling	75.40	16.40	19.90	4.55
Preserved 6 months in cold storage without stifling	106.90	24.50	22.90	6.80
Preserved 12 months in cold storage without stifling	96.80	31.50	32.50	8.70
Preserved 18 months in cold storage without stifling	98.90	27.80	24.10	7.71

*At 5% level of statistical confidence; No of observations (N): 50
Confidence interval (CI) = Std. dev. /$N^{0.5}$X 1.96

Table 6: Non- broken filament length (NBFL) of Raily tasar cocoons

Type of cocoons	Non- broken filament length (NBFL)			
	Average (m)	Standard deviation (SD) (m)	Co- efficient of variance (CV) (%)	Confidence interval (CI)*
Green/Harvested	108.30	10.70	9.85	2.96
Stifled/Hot air dried	102.10	8.57	8.40	2.38
Preserved 6 months in net cage after stifling	99.80	10.00	10.00	2.80
Preserved 12 months in net cage after stifling	75.90	15.60	20.60	4.30
Preserved 18 months in net cage after stifling	72.40	16.90	18.40	4.69
Preserved 6 months in cold storage without stifling	98.80	20.70	21.00	5.70
Preserved 12 months in cold storage without stifling	100.50	19.60	19.50	5.40
Preserved 18 months in cold storage without stifling	97.90	17.45	18.25	4.84

*at 5% level of statistical confidence; No of observations (N): 50
Confidence interval (CI) = Std.dev./$N^{0.5}$X 1.96

The significant reduction of NBFL after 12- & 18- months storage of stifled tasar cocoon in net cage was due to excessive breaks occurred during yarn withdrawal. Reelability (%), raw silk recovery (%) as well as the quality of yarn in terms of cleanness, neatness, breaking elongation and tenacity were found better in low temperature and humidity. The effect of humidity and temperature on reeling parameters and quality of yarn may be due to structural changes in sericin due to high humidity during spinning of cocoons (Naik and Somashekar, 2004; Naik and Somashekar, 2008; Singh *et al*., 2011).

From the evaluation of absorption peak found by Fourier Transform Infrared spectroscopy for amide 1, 2 and 4 of sericin; it was observed that there will be difficulty in dissolution of β- structure. The formation of β- structure of sericin is due to higher humidity in atmosphere. Sericin I of structure like random coil absorbs moisture and that's why the intra molecular hydrogen bonds got snapped due to the presence of water molecules. So, the structure which was earlier folded becomes unfolded followed by shifting to β- structure which is difficult to dissolve. So, there will be reduction in solubility of sericin structure which affect the cooking efficiency as well as reeling performance of mulberry cocoons (Komatsu, 1980; Kataoka, 1977).

Hence, excessive breaks are occurred during yarn withdrawal of reeling process results inferior NBFL of tasar cocoons.

Single filament denier

The denier of tasar silk filament yarn is shown in Table 7 & 8 for Modal & Raily ecoraces for green, stifled and stored varieties.

Table 7: Single filament denier of Modal tasar cocoons

Type of cocoons	Single filament denier			
	Average	Standard deviation (SD)	Co-efficient of variance (CV) (%)	Confidence interval (CI)*
Green/Harvested	11.00	1.09	9.90	0.30
Stifled/Hot air dried	10.54	0.81	7.64	0.22
Preserved 6 months in net cage after stifling	10.45	0.72	6.90	0.20
Preserved 12 months in net cage after stifling	11.10	0.76	6.85	0.21
Preserved 18 months in net cage after stifling	10.95	0.80	6.50	0.22
Preserved 6 months in cold storage without stifling	10.56	0.56	5.32	0.16
Preserved 12 months in cold storage without stifling	10.90	0.60	5.50	0.17
Preserved 18 months in cold storage without stifling	11.05	0.58	6.10	0.16

*at 5% level of statistical confidence; No of observations (N): 50
Confidence interval (CI) = Std. dev./$N^{0.5}$X 1.96

Table 8: Single filament denier of Raily tasar cocoons

Type of cocoons	Single filament denier			
	Average	Standard deviation (SD)	Co- efficient of variance (CV) (%)	Confidence interval (CI)*
Green/Harvested	11.20	0.74	6.60	0.20
Stifled/Hot air dried	11.07	0.88	7.96	0.24
Preserved 6 months in net cage after stifling	11.60	0.80	6.90	0.20
Preserved 12 months in net cage after stifling	11.80	0.67	5.70	0.19
Preserved 18 months in net cage after stifling	10.90	0.69	5.85	0.19
Preserved 6 months in cold storage without stifling	10.90	0.56	5.15	0.16
Preserved 12 months in cold storage without stifling	11.40	0.70	6.10	0.20
Preserved 18 months in cold storage without stifling	11.60	0.82	6.25	0.23

*At 5% level of statistical confidence; No of observations (N): 50
Confidence interval (CI) = Std. dev./$N^{0.5}$X 1.96

It was found that no difference of single filament denier between all types of cocoons. Previous studies also reported the same trend for tasar Daba eco- race (Chattopadhyay *et al*., 2022).

Reeling performance

Reelability (%)

The reelability (%) of green, stifled and 6-month, 12 month & 18 months stored stifled net cage rack stored & cold storage preserved Modal as well as Raily cocoons are given in Table 9 & 10.

Table 9: Reeling performance of Modal tasar cocoons

Parameters		Type of cocoons						
	Green/ Harvested	Stifled	Preserved in net cage after stifling (months)			Preserved in cold storage without stifling(months)		
			6	12	18	6	12	18
	Reelability (%)							
Average	23.50	22.60	21.80	18.70	15.30	22.00	21.60	20.20
Std. dev. (S.D.)	1.62	1.87	0.90	0.70	0.85	0.98	0.78	0.95
C. V. (%)	7.18	8.64	4.10	4.32	4.58	4.37	3.67	4.32
C.I. (5%) (±)	1.87	2.14	1.03	0.80	0.98	1.12	0.90	1.09
	Raw silk recovery (%)							
Average	52.60	55.60	51.00	50.70	48.54	54.60	51.50	49.89
Std. dev. (S.D.)	0.42	0.69	0.70	0.82	0.84	0.40	0.75	0.45
C. V. (%)	0.81	1.28	1.29	1.62	1.82	0.75	1.45	2.05
C.I. (5%) (±)	0.48	0.80	0.79	0.94	0.96	0.46	0.86	0.52
	Yield/1000 cocoons (g)							
Average	1290.00	1370.50	1100.60	1085.40	1043.35	1230.80	1180.80	1125.40
Std. dev. (S.D.)	22.30	79.80	74.70	63.50	69.55	15.10	25.60	35.20
C. V. (%)	1.72	6.34	5.96	5.77	6.20	1.16	2.00	2.89
C.I. (5%) (±)	25.60	91.52	85.90	73.00	79.83	17.40	29.43	40.40

No of observations N = 5 (50 cocoons/observation); Std. dev. (S.D.): Standard deviation;
C.V. (%): Co- efficient of variance;
C.I (5%): Confidence interval at 5% statistical confidence level = S.D. X 2.571/$N^{0.5}$

Table 10: Reeling performance of Raily tasar cocoons

Parameters	Type of cocoons							
	Green/ Harvested	**Stifled**	**Preserved in net cage after stifling (months)**			**Preserved in cold storage without stifling (months)**		
			6	**12**	**18**	**6**		**18**
	Reelability (%)							
Average	21.50	22.30	19.60	17.30	16.20	20.70	20.10	21.33
Std. dev. (S.D.)	0.95	0.87	0.78	0.90	0.85	0.68	0.98	0.75
C. V. (%)	4.10	3.80	3.40	5.70	4.32	2.98	4.37	3.67
C.I. (5%) (±)	1.09	1.00	0.90	1.03	0.97	0.80	1.10	0.86
	Raw silk recovery (%)							
Average	53.10	52.50	51.75	49.40	49.35	52.75	51.60	53.30
Std. dev. (S.D.)	0.36	0.40	0.50	0.69	0.48	0.70	0.45	0.52
C. V. (%)	0.68	0.72	0.94	1.34	1.20	1.30	0.84	1.53
C.I. (5%) (±)	0.41	0.44	0.57	0.80	0.55	0.80	0.52	0.60
	Yield/1000 cocoons (g)							
Average	1360.50	1415.00	1355.70	1205.50	1165.46	1380.00	1290.80	1280.70
Std. dev. (S.D.)	13.53	17.63	23.90	74.68	35.45	15.10	14.70	16.75
C. V. (%)	1.03	1.35	1.83	5.96	3.25	1.20	1.15	1.35
C.I. (5%) (±)	15.60	20.27	27.50	85.90	40.69	17.30	16.90	19.22

No of observations N = 5 (50 cocoons/observation); Std. dev. (S.D.): Standard deviation;
C.V. (%): Co- efficient of variance;
C.I (5%): Confidence interval at 5% statistical confidence level = S.D. X $2.571/N^{0.5}$

It was observed that no difference occurred for reelability (%) between green, stifled and preserved tasar cocoons in net cage for six months after stifling as well as in cold storage for 6, 12 and 18 months without stifling. but there is some reduction observed in case of net cage stored stifled cocoons for 12 and 18 months.

Due to stifling/hot air drying, only moisture present in cocoons shells along with pupae fluid are evaporated. Hence, only significant reduction of cocoon weight was observed (Jolly *et al*., 1979; Mishra *et al*., 2020; Das 2020; Khan *et al*., 2019). So, no change of reelability was observed. But for 12 & 18 months stifled and net cage preserved cocoons, due to transformation of structure, the crystallinity of sericin increases. So, solubility of sericin reduced during softening process for mulberry, tasar as well as muga cocoons (Naik, S. V. and Somashekar, T. H. 2004; Naik, S. V. and Somashekar, T. H. 2008). Hence, excessive breaks are occurred during withdrawal of reeling process results inferior reelability of 12- & 18-months net cage preserved stifled tasar cocoons.

Raw silk recovery (%)

The raw silk recovery (%) of all types of cocoons are shown in Table 9 &. This is because raw silk recovery is the ratio of yarn weight to the total of yarn and waste weight expressed as percentage. There is marginal reduction of raw silk recovery for 12- & 18-months net cage stifled preserved cocoons of both Modal & Raily ecoraces, which is mainly due to increase of waste. Studies reported about no alteration of raw silk recovery of tasar cocoons due to stifling and storage for different eco-races cocoons (Gahlot *et al*., 2003; Mazumdar *et al*., 2012). Marginal reduction of silk yarn production due to increase of waste during reeling at breaks for 12-& 18 months net cage stifled preserved cocoons.

Yield/1000 cocoons (g)

The yield/1000 cocoons of all types of cocoons are shown in Table 9 & 10. Although, no significant difference exists for yarns produced from cocoons stored up to six-month in net cage after stifling and 6-, 12- and 18-months in cold storage without stifling, but significant reduction of yarn weight was observed for 12- & 18-months net cage stored stifled cocoons.

Conclusions

Cocoon weight reduces significantly about 60% due to stifling as compared to green Modal & Raily tasar cocoons. Also, same amount of reduction was observed for cold storage preserved cocoons. Which is because of elimination of moisture and pupae body fluid from cocoons. No change of shell weight was found between all cocoon varieties except marginal reduction after stifling. Filament length remains same after stifling and preservation (up to six-month net cage after stifling and 6-, 12- and 18-months cold storage without stifling cocoons) except little reduction for 12- & 18-months storage in net cage after stifling were observed. Non- broken filament length (NBFL) reduced significantly for 12 & 18 months stifled net cage stored tasar cocoons due to excessive breaks occurred during single cocoon reeling by Epprouvette. This is due to increase of sericin crystallinity as the change of structural conformation occurs due to absorbance of moisture. Similarly, single filament denier remains at par between all Modal & Raily varieties. Due to significant deterioration of non-broken filament length (NBFL); excessive breaks were occurred during reeling for yarn production in case of 12- & 18-months net cage stifled preserved Modal & Raily cocoons and thereby reelability (%) reduces significantly. For other varieties of cocoons, reelability remains at par. No significant change of raw silk recovery as well as yield/1000 cocoons were observed between green, stifled and preserved (up to six-month net cage after stifling and 6-, 12- and 18-months cold storage without stifling cocoons) Modal & Raily eco-race tasar cocoons. There is some reduction of raw silk recovery and yield/1000 cocoons for 12- & 18-months net cage rack preserved stifled because of enormous breaks occurred during reeling. So, the reeling waste also increases whereas deflossing and pelade wastes remain same.

So, it can be opined that, Modal & Raily tasar cocoons may be preserved in cold storage without stifling for future reeling purpose and hence the single cocoon characteristics and reeling performance need to be evaluated after 24-months preservation along with sericin characterization.

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