NC STATE UNIVERSITY

JTATM

JOURNAL OF TEXTILE AND APPAREL, TECHNOLOGY AND MANAGEMENT

Volume 5, Issue 4, Fall 2007

Evaluation of Raw Silk Produced by Bivoltine Silkworm Bombyx mori L. (*Lepidoptera: Bombycidae*) Races in Kenya

E. K Nguku[1, 2*], V. V. Adolkar[1], S. K Raina[1], K. G. Mburugu[2], O. M. Mugenda[2]

International Center of Insect Physiology and Ecology, P. O. Box 30772 - 00100, Nairobi, Kenya.
Kenyatta University, P. O. Box 42844 - 00100, Nairobi, Kenya.

*Corresponding author:
Fax: +254 – 20 - 8632001/2
Phone: +254 – 20 – 8632000
Email: enguku@icipe.org

ABSTRACT

Evaluation of raw silk produced in location S1 (laboratory) and S2 (field) was assessed during long rains (LR) and short rains (SR), using selected bivoltine Bombyx mori silkworm strains initially obtained from China and India. They included Chun Lei X Zen Zhu (C X Z), Quifeng X Baiyu (Q X B), Quingsong X Haoyoe (Q X H), 75xin X 7532, Suju X Minghu (S X M) and ICIPE I.

This study aimed to evaluate the quality of raw silk produced by the domesticated silkworm B. mori L in Kenya. Silkworm rearing was done following the procedure of Jolly (1987). Setting of the silk quality control lab was done following specifications from the Chinese Academy of Agricultural Sciences (CAAS) and the International Silk Association, Lee (1999). Raw silk characteristics were evaluated and performance tested to determine its suitability for silk production. Quality tests of each post-harvest production process were carried out to establish the overall quality of the product. Silk winding breaks varied amongst the different strains, with ICIPE I having the least counts while 75xin recorded the most counts 13, 16, 12 and 12 during/in SR S1, SR S2, LR S1 and LR S2 respectively. Elongation percentages differed between the seasons and strains, between 18 and 20%. It was also observed that silkworm strains with high elongation count had the least number of winding breaks. ICIPE I had an average elongation of 20% and an average of 5 winding breaks counts, whereas 75xin had 18% and 13 of the same respectively.

Cleanliness and neatness percentages differed among the strains and were within the acceptable ISA standards but notably ICIPE I cleanliness and neatness percentages were higher than the other silkworm strains during the two seasons, 97 and 96% respectively.

The data obtained identified ICIPE I as a more economical strain to rear for quality production of raw silk and yarn.

Keywords: Silkworm (Bombyx mori), winding breaks, elongation, neatness, cleanliness

Introduction

A highly valued animal fiber, silk has long been used for the production of luxurious textiles of the finest quality (Shelagh, 2004; Welford, 1969). It is one of the most ancient and preferred fiber in the world due to its natural texture, strength and fineness (Schenk, 1981).

The mulberry silkworm otherwise known as the *B. mori* spins valuable silk fibers making it one of the most beneficial insects to mankind, and is becoming an attractive multifunctional material for both textile and non-textile uses (Tsukada *et al*., 2005). The finest quality raw silk and the highest fiber production come from the commonly domesticated silkworm, *B. mori*, (Sericulum, 2000). Although there are several commercial species of silkworms, *B. mori* is the most widely used and intensively studied, and techniques for its rearing are the most improved. This insect is the sole living species in its family, Bombycidae, and has been domesticated for so long that it probably no longer survives in the wild (Cherry 1993).

Silk has an economic value that is higher than that of other natural fibers such as cotton and wool because of its superior characteristics. The steadily growing demand for silk in the silk consuming countries indicates excellent opportunities for any country to increase her silk production (Kumar, 1995), an opportunity valuable for Kenya to embark on. In order to secure this opportunity, it is consequently important for production of silk products to be of utmost quality.

Africa's enormous potentials in raw silk production (Hardingham, 1996; ICIPE, 1997) are faced with some limitations, which are likely to pose a setback to local cocoon producers. Apart from the lack of infrastructure and sufficient inputs, sericulture industry in Africa faces lack of technical expertise at various levels of the production activities (Akinkunmi and Odeyibi, 2001). Sericulture development in Kenya has been constrained because of the insufficient technological expertise in the silk production processes and processing requirements of cocoons. While cocoon production is a typical farming activity, it is only part of a chain of activities that needs to be completed to produce high-value raw silk outputs.

The properties of any fiber determine the performance of the fabric produced from it (Down, 1999). Testing of silk yarn production processes is essential for the production of quality yarn and fabric (Garner, 1967). It ensures efficiency and harmony in the production process, and the final product is of high quality (SSC, 1995). Conversely, availability of silkworm breeds is the prime requisite for the development of the silk industry. Mulberry sericulture being almost a new venture in this region depends to a large extent on the introduced breeds and the stability of silk industry greatly depends on the locally adapted breeds. Emphasis is laid on the entire set up of post-harvest quality control and seed organization, for steady and consistent production of quality silk yarn.

With this background, this study addressed issues concerned with production of high-value raw silk outputs. There has been no study carried out in Kenya, to evaluate the quality of raw silk produced by the available *B. mori* silkworm strains. This research therefore evaluated the raw silk properties and quality standards produced by six selected *B. mori* silkworm strains, ICIPE I, C X Z, Q X B, Q X H, S X M and 75xin.

In addition the study determined the suitability of the six selected *B. mori* silkworm strains for silk production in Kenya. A comparative study of the silkworm strains reared in two locations, during two seasons with three replications was done. Quality tests of each post-harvest production process were carried out to establish the overall quality of the product.

Methodology:

Reeling of silk
Cocoons were sorted and a multi-end reeling machine used to reel them into raw silk. Tests were performed to certify their characteristics, performance and quality as follows:

Winding breaks
To test for winding breaks, sample silk skeins each weighing 70g were picked from each strain. The sample skeins were fitted onto the winding frame and the end attached to a bobbin. Winding was carried out at an average speed of 110 metres/min for duration of 60 minutes. The number of breaks that occurred were counted and noted. The cause of each break was noted.

Elongation percentage
A serigraph was used to test for the degree of elongation (percentage). A sizing reel of 1.125m in circumference (400 revolutions equal to 450m) and a constant speed of 300 revolutions per minute were used to prepare the test sample. The sample skeins were conditioned in a room maintained at a standard temperature of 20^{O}C and relative humidity of 66%. The clamp distance was 10cm and the extension speed 15cm per min. The sample skeins were mounted on the serigraph and elongation expressed in percentage of total stretch of the portion tested.

Cleanliness Testing
This test was carried out to determine imperfections in the silk filament. Cleanliness defects were classified as super major defects, major defects and minor defects. Samples were drawn randomly and compared with the ISA standard photos.

The cleanliness inspection was done from a position of 0.5metres (2 feet) directly in front of the Seri board inspection panels. The actual number of cleanliness defects of each class and kind were counted on the yarns on both sides of the inspection panel, omitting the parts on its edge. The kind and class to which each defect belongs was determined by comparing it with the standard photographs for cleanliness defects. Each defect carries penalty points and the difference of the total penalty points from 100 gives the test results.

Neatness test
Inspection was conducted from a distance of 0.5 meters (2 feet), directly in front of the inspection panels. Each panel on any one side of the inspection board was carefully compared with the standard photographs for neatness, and its neatness value estimated in percentages. From 100 to 50 percent the estimate was made to the nearest 5 percent, while below 50 percent the estimate is made to the nearest 10 percent.

RESULTS

Winding Breaks counts
Upon performing quality tests on the raw silk the winding breaks counts showed that 75xin had the highest number of winding breaks in both locations in the two seasons. During SR in S2, it recorded a total of 16 counts, the highest recorded for the duration of the study. ICIPE I had the least with only 6 counts, in the same setting. Winding breaks in the other strains ranged between 13 and 8 counts. It was noted that silk harvested during SR had more breaks compared to those of the LR. This tendency was also perceived in silk from the two locations. S2 location had more breaks in most strains (Fig 1).

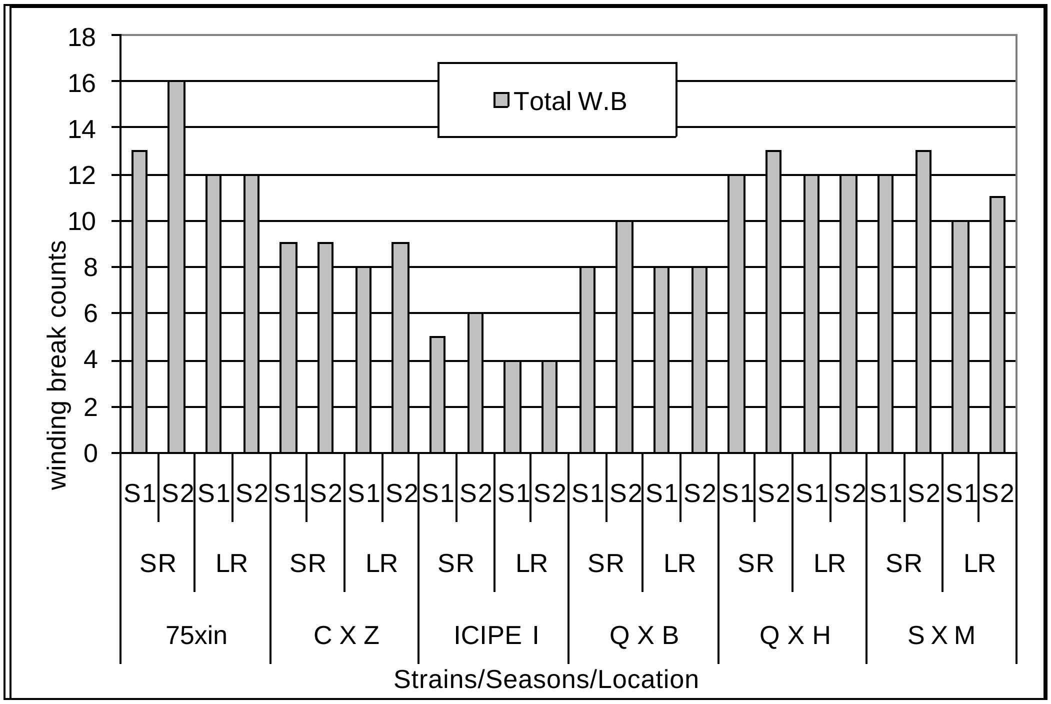

Fig 1. Total Winding Breaks Count during LR & SR in S1 & S2

An analysis of the two major causes of winding breaks was performed. It was apparent that the winding breaks were mainly caused by size deviation compared to split ends (Fig 2). Size deviation accounted for 60 - 100% of the winding breaks counts. During LR in S1, 100% of ICIPE I's winding breaks were caused by size deviation**.**

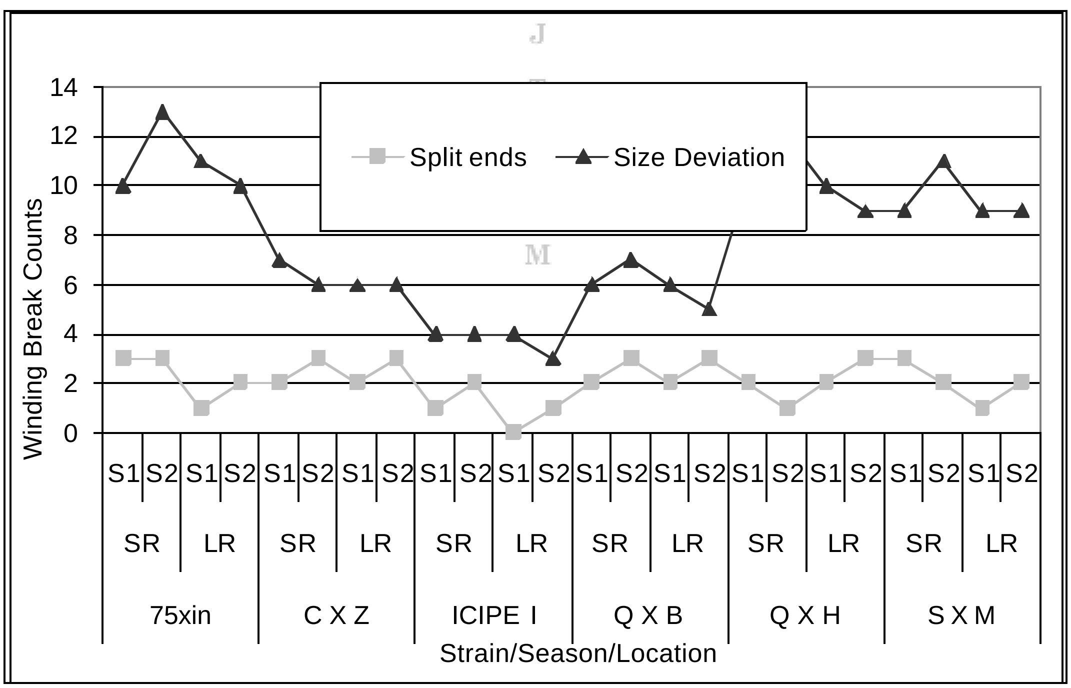

Fig 2. Comparative Winding Breaks Count during LR & SR in S1 & S2

Raw silk elongation percentage

The study revealed that elongation for the six silkworm strains studied was between 18 and 20%. ICIPE I had elongation percentages between 19 and 20% and C X Z had mainly 19%. The other strains largely had elongations of 18% (Fig 3). It was evident that the silk harvested during LR had a minimal higher average elongation percentage of 19% compared to silk harvested during SR, which had an average percentage of 18%.

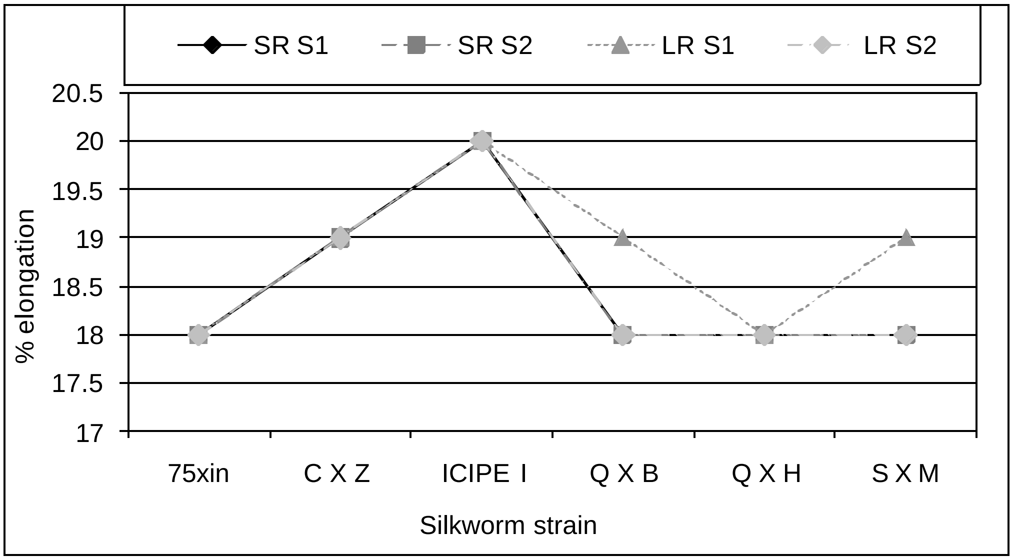

Fig 3. Percent Elongation during LR & SR in S1 & S2

A study was performed to compare the elongation percentage and breaking counts. After plotting the elongation and winding curve, it was noted that silkworm strains having the highest elongation count, had the least winding breaks and vice verse (Fig 4). ICIPE I had an average elongation of 20% and an average of 5 winding breaks counts, whereas 75xin had 18% and 13 of the same respectively.

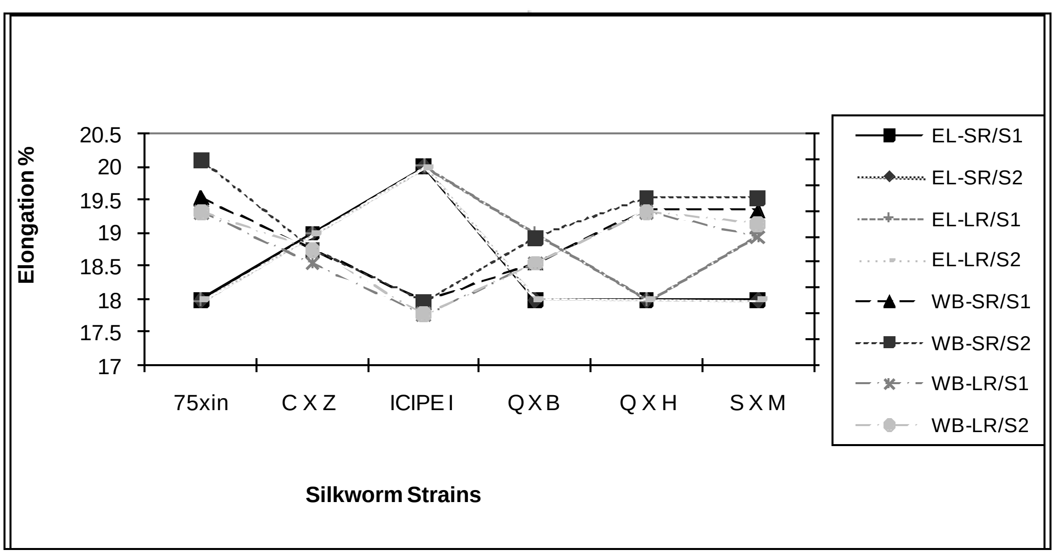

Fig 4. Winding and Elongation during LR & SR in S1 & S2

Cleanliness and Neatness Percentages of B. mori *raw silk*

Cleanlinesss percentages were highest in ICIPE I at 97.0 ± 0.333% and 96.2 ± 0.359% during LR, S1 &S2 respectively and 96.0 ± 0.211 and 96.0 ± 0.258% during SR, S1 &S2 respectively. The lowest percentages recorded were Q X H, which had 89.9 + 0.379 and 88.3 + 0.260% during LR, S1 & S2 respectively, and 90.0 ± 0.333 and 88.0 ± 0.422% during SR, S1 &S2 respectively.

ICIPE I recorded the highest neatness percentages during LR as well as SR in both locations, S1 and S2 as follows 93.0 ± 0.394 and 92.9 ± 0.180% respectively and 94.3 ± 0.300 and 93.3 ± 0.473% respectively. 75xin on the other hand recorded the lowest percentages.

There were significant differences in cleanliness percentages in some strains during the two seasons and locations (Waller-Duncan K-ratio t test at a = 0.05 significant level was used). However there was no significant difference in the cleanliness percentages of ICIPE I and C X Z. In the neatness test there was no significant differences in the percentages of ICIPE I and Q X H (Table I).

Table I. Mean cleanliness and neatness % in S1 & S2 during LR & SR

Strain	**Season**	**Location**	Mean cleanliness	**Mean Neatness**
75xin	LR	S1	92.8 ± 0.133 c	87.1 ± 0.180 d
	LR	S2	91.0 ± 0.211 e	85.0 ± 0.211 d
	SR	S1	92.0 ± 0.211 d	87.1 ± 0.379 c
	SR	S2	91.2 ± 0.359 c	85.0 ± 0.258 c
C X Z	LR	S1	94.4 ± 0.163 b	88.9 ± 0.180 c
	LR	S2	94.0 ± 0.211 b	88.2 ± 0.249 b
	SR	S1	94.0 ± 0.211 b	88.0 ± 0.258 b
	SR	S2	92.9 ± 0.233 b	87.0 ± 0.211 b
ICIPEI	LR	S1	97.0 ± 0.333 a	93.0 ± 0.394 a
	LR	S2	96.2 ± 0.359 a	92.9 ± 0.180 a
	SR	S1	96.0 ± 0.211 a	94.3 ± 0.300 a
	SR	S2	96.0 ± 0.258 a	93.3 ± 0.473 a
Q X B	LR	S1	92.8 ± 0.291 c	88.3 ± 0.300 c
	LR	S2	92.0 ± 0.298 d	88.2 ± 0.291 b
	SR	S1	92.2 ± 0.133 d	87.9 ± 0.314 b
	SR	S2	90.2 ± 0.327 d	87.3 ± 0.300 b
Q X H	LR	S1	89.9 ± 0.379 d	89.1 ± 0.407 b
	LR	S2	88.3 ± 0.260 f	88.0 ± 0.258 b
	SR	S1	90.0 ± 0.333 e	88.1 ± 0.180 b
	SR	S2	88.0 ± 0.422 e	87.2 ± 0.389 b
S X M	LR	S1	94.1 ± 0.233 b	87.4 ± 0.400 d
	LR	S2	93.0 ± 0.212 c	87.3 ± 0.396 c
	SR	S1	92.9 ± 0.100 c	88.0 ± 0.333 b
	SR	S2	90.8 ± 0.133 c	85.0 ± 0.258 c
F value	LR	S1	172.96	97.12
	LR	S2	184.21	194.41
	SR	S1	201.58	282.20
	SR	S2	183.34	288.21

Means followed by the same letter(s) in the same column are not significantly different. Waller-Duncan K-ratio t test at a = 0.05 significant level was used.

It is evident that location S1 was recorded as having produced better raw silk in terms of cleanliness and neatness, as opposed to S2 during the two seasons. Cleanliness and neatness percentages were however within the acceptable ISA standards.

DISCUSSION

When breaks occur during winding it is necessary to note the cause of each break. In this study the raw silk winding breaks varied among the different strains. Hall, (1980) observations that the silkworm is not quite perfect in it's spinning of silk for the thread changes in diameter from the beginning to the end of the cocoon uncovers a possibility that may have contributed to the causes of winding breaks in this study. Aruga (1994) adds that from the beginning to the end of the spinning by mature larvae, the process of spinning the fiber is not uniform. He also noted that silkworm strains have varying characteristics in their spinning of silk thread, which could be a contributing factor to the winding breaks variation. This trend could be as a result of the different strains, which produce silk filaments of differing thickness. Consequently upon reeling, variations were present that may have contributed to the high count of winding breaks due to size.

The reeler plays a major role in the production of raw silk. To maintain reeling thread in the required size, the average cocoon number per thread must be adjusted in order to produce silk thread in the same size throughout all ends during reeling (Lee, 1999). This is a factor that could have led to size deviation in the raw silk. Practical experience has proven that winding alters the yarn structure (Vijayakumar, 2003). This is a phenomenon, which may affect standard deviation of silk and increase breaking tendencies. In this study, the major causes of winding breaks were size deviation and split ends, whereby the former contributed to between 60 and 100% of the winding breaks amongst the strains.

It was noted that elongation percentages differences during LR and SR were minimal at 19 and 18% respectively. These percentages compare with (Lee, 1999); who states that raw silk has an elongation of 18 – 23% of its original length. He further adds that moisture increases the elongation of silk and decreases its tenacity. The seasons for that reason did not affect the elongation percentages of the silk. It was observed that silkworm strains having the highest elongation count, had the least winding breaks and vice verse. ICIPE I had an average elongation of 20% and an average of 5 winding breaks counts, whereas 75xin had 18% and 13 of the same respectively. This relates to research by the Vegan Society, (2003) which shows that when silk is dry the elongations (elastic recovery) varies from 10-25% and when wet it will elongate as much as 33-35%. This relationship of high elongation percentage and low winding breaks could have been as a result of increased elasticity of the fiber, hence fewer breaks on the fiber occur.

Raina (2000, 2004) points out that late age silkworms require 70% relative humidity and a temperature of 24^{O}C. Humidity that goes above 70% may give raise to breaks during reeling and decrease silk quality. There is a possibility that humidity in S2 may have risen above the optimum and thus the higher number of breaks noted in silk harvested from that location.

Research by Vijayakumar (2003) indicated that if winding tension is selected properly, the following tensile properties are not affected: tenacity, elongation and breaking strength. The winding tension and speed for this study was adjusted and maintained according to denier of the raw silk. This ensured that during winding the required speed for respective deniers were maintained to avoid inconsistent data on winding break counts.

Silk neatness and cleanliness differed among the silkworm strains reared, in this study.

Neatness defects are imperfections in silk yarn, which are smaller than minor cleanliness defects. On average, ICIPE I had the highest percentages of these two parameters 96 and 93% respectively, during the two seasons. On the other hand, the other strains had varied percentages. Q X H had the lowest cleanliness percentage while75xin had the lowest neatness percentage LR and SR. Hair-like projections in silk fiber called lousiness are defects that occur in silk fiber and affect neatness. Lousiness is more prevalent in baves produced by silkworms, which have been overfed in the fifth instar. Another factor promoting lousiness is mounting over mature silkworm larvae (Lee, 1999). In this study it is significant to point out that neatness for all the strains reared in S1 and S2 during LR and SR were within the international standards and the above mentioned factors might not have been prevalent.

Aruga (1994) attributes this kind of occurrence (neatness and cleanliness defects) to the technique applied in the cooking and reeling of cocoons. In this study identical techniques were utilized for the cooking and reeling the cocoons. It is not probable for varying techniques to have contributed to the results. On the other hand Lee (1999) research shows that a characteristic of the silkworm race may give rise to cleanliness and neatness defects. This may have contributed in the slight variations that were noted in these two parameters for the silkworm strains. There has been no mention of the effect of the environmental conditions, however from the study, it was noticed that S1 produced silk of better quality in terms of neatness and cleanliness. There is a possibility that environmental conditions affected the development of the larvae (Aruga, 1994), which consequently gave raise to cocoons with the said flaws.

Conclusion

It was evident from the study that rearing of the *B. mori* silkworm during the LR in S1 produced finer results to those of SR in S2. It was also apparent that ICIPE I strain performance was superior to the other strains used in this study. However it is important to note that the results were within the ISA standards. For the production of quality raw silk it would be advisable to use ICIPE I strain and C X Z while 75xin should be used with utmost vigilance.

It is important to note that the many different processes of silk production, the many different applications and the many different people concerned require different information about the quality and the behavior of the silk yarn or thread. In reeling, twisting, weaving or dyeing, several quality aspects are of importance and must be known, but each process has different needs (SSC, 1995).

References

Akinkunmi, O. A and Odebiyi, J. A. (2001). Chemical control of *Anthrenus oceanicus* attacking stored cocoons of the silkworm with commercial formulations containing permethrin, tetramethrin, phenothrin and allethrin. Pakistan Journal of Biological Sciences 4 (4): pp 400-401

Aruga, H. (1994). Principles of sericulture. Oxford and IBH publishing Co. Pvt. Ltd, 66 Janpath New Delhi, India, pp. 376.

Cherry, R. (1993). Sericulture. Bull. Entomol Soc. Am (35:83 – 84)

Down, J. (1999). Design and technology. Textile Technology to GCSE. Oxford University Press

Garner, W. (1967). Textile lab manual: Additional methods. Vol 6. Cox and Wyman Limited, London

Hardingham, M. (1996). The potentials for silk in Africa. Spore No. 61 pp5

ICIPE (1997). Spinning a yarn from the wild. Spore No. 71 pp6

Jolly, M.S. (1987). Appropriate sericulture techniques (Ed. Jolly, M.S) ICTRETS, Mysore, India, pp.75.

Lee, Y-W. (1999). Silk reeling and testing manual. FAO Agricultural Services Bulletin No. 136. Rome, Italy.

Raina, S.K. (2004). A Practical Guide For Raising and Utilizing Honey Bees and Silk worms in Africa. Commercial Insects. IBRA Press, UK in seven Languages. pp 164.

Raina, S. K. (2000). The Economics of Sericulture and Apiculture Modules for Income Generation in Africa. IBRA, UK, pp 86.

Sericulum (2000). The remarkable silkworm. The science of silkworms for the course of nature.

Shelagh, V. (2004). Chinese silk: A cultural history, London, British Museum Press, pp 6 – 17

(SSC) Silk Standards Committee (1995). Raw silk. Manual for testing, classifying, quality limits, grading. Directives, methods. Standards. Instrumentation. International Silk Association. Silk Congress Brighton, Great Britain.

Tsukada, M., Islam, S., Arai, T., Bosch, A., and Fred, G. (2005). Microwave irradiation technique to enhance protein fiber properties. Autex Research Journal Vol. 5, No 1

Vijaykumar, T. (2003). Textile technology, Indonesia

Welford, T. (1969). The textile student manual. 6th Edition Isaac Pitman and Sons Ltd, Great Britain