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Evaluation of Some Physical Characteristics of Mulberry Cocoons Produced in Ghana

J. Amoah
CSIR-Institute of Industrial Research
P. O. Box LG 576, Legon, Accra, Ghana
Email: joeamoah@yahoo.com,

K. Akufo-Kumi
CSIR-Institute of Industrial Research
P. O. Box LG 576, Legon, Accra, Ghana

W. O. Oduro
CSIR-Institute of Industrial Research
P. O. Box LG 576, Legon, Accra, Ghana

R. NaaNorkor Baddoo
University of Ghana, Dept. of Crop Science, Legon- Accra, Ghana

M. A. B. Animpong
CSIR-Institute of Industrial Research
P. O. Box LG 576, Legon, Accra, Ghana

C. Odoom
CSIR-Institute of Industrial Research
P. O. Box LG 576, Legon, Accra, Ghana

Abstract **– Sericulture was formally introduced to Ghanaian farmers in 1993 which led to the establishment of pilot farms and a Silk Production and Demonstration factory in 2004. This study evaluated some physical characteristics of mulberry silk cocoons produced from ten farms selected on the basis of a three year production history. The characteristics evaluated included dry cocoon weight, shell weight, shell ratio, cocoon length, and cocoon width. Dry cocoon weight ranged between 0.395 ± 0.089 gm and 0.377 ± 0.098 gm. Cocoon shell weight was between 0. 241±0.055 gm and 0.257±0.092 gm. The maximum Cocoon shell ratio was 66.5± 11.4 while the minimum was 62.3± 12.1. Variability in the size of cocoons based on the mean cocoon index ranged from 172.39 to 179.90. The lowest standard deviation was 7.90 and the highest was 20.6. Coefficient of variation on the cocoon indices from the ten farms ranged between 4.41 to 11.98. No statistically significant difference was found among the characteristics of cocoons produced from all the ten (10) farms; however on the basis of standard deviation of 8 or less with minimal co-efficient of variation (CV) for cocoon indices, four farms, Mampong (Cocoon Index of 7.90 and co-efficient of variation 4.41), Amartey (Cocoon Index of 7.97 and co-efficient of variation 4.58), Kyeremeh (Cocoon Index of 7.98 and co-efficient of variation 4.46) and Helix farms (Cocoon Index of 8.02 and co-efficient of variation 4.52) produced cocoons that are least variable in shape.**

Keywords **– Sericulture, Cocoon Index, Characteristics, Variability.**

I. Introduction

Sericulture is the practice of rearing silkworms for the production of silk. It begins on the upstream side with the systematic establishment of a mulberry farm or plantation which is the food plant for rearing silkworms. Eggs of silk-producing insects or moths (Bombyx Mori) are hatched and made to pass through a caterpillar or worm stage during which each caterpillar spins for itself a cocoon. A further process of metamorphosis is terminated at this stage through stifling which prevents the insect from emerging out of the cocoon as a moth.

A cocoon is actually an unbroken fibre secreted from the caterpillar's body which can be unwound, through reeling thereby producing the silk fibre of commercefrom which silk cloth and silk fabrics are made

There are several varieties of silk worms that are reared for the production of natural silk fibre nonetheless; Ghana adopted the Bombyx Mori; which is a silk worm that feeds on the leaves of the Mulberry plant. Eggs of Bombyx Mori are currently being imported mostly from India for silk production.

Sericulture is an effective means of socio-economic development of rural areas and is ideally suited for developing countries having a large rural population. It is therefore promoted mainly as an agro-based, labour intensive rural oriented cottage industry, providing gainful employment mainly to the weaker and marginalized sections of the society and requiring little capital investment. It is estimated that sericulture can generate employment @11 man days per kg of raw silk production (in on-farm and off-farm activities) throughout the year.[1] Silks are known for their high strength, durability, luster, drapeability, and other unique features compared to the common cellulose and synthetic fibers in current use. However, the amount of silk produced world-wide is only about 1.6 million tons compared to about 65 million tons of fibers produced worldwide every year [2].

A highly valued animal fibre, silk has long been used for the production of luxurious textiles of the finest quality [3]. Silk has an economic value that is higher than that of other natural fibres 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 production [4].

The climate of Ghana is tropical with annual rainfall ranging from about 1,100 mm in the north to about 2,100 mm in the southwestand is well suited for the growth of the mulberry plant and also for the rearing of cocoons. Ghana is one of the most favored countries in theAfrican region in terms of rainfall, temperature, humidity, sunshine and soils for mulberry cultivation and the rearing of silkworms [5].

Silkworm rearing and cocoon production was formally introduced into Ghana through the implementation of a project entitled "Sericulture and Silk Processing Development" sponsored by The Food and Agriculture Organization (FAO). The objective of the project was to assist small scale farmers in cocoon and raw silk production through the provision of basic techniques and essential equipment and tools for silkworm rearing and cocoon processing, while making additional employment and income opportunities available to them. This project was executed by the Ministry of Food and Agriculture with implementation arrangements with the Institute of

Industrial Research of the Council for Scientific and Industrial Research (CSIR-IIR).

The sericulture industry in Ghana has since its inception received technical assistance from the Food and Agriculture Organization (FAO) of the United Nations. In 1993, 1995 and 1997, the FAO sponsored a consultant to Ghana to look into the feasibility of the Sericulture industry in the country and also assist the government of Ghana and the Sericulture Association to prepare a project proposal for possible sponsorship by the FAO under a Technical Co-operation Programme (TCP).[5]

The first organized and formal training of farmers in sericulture was undertaken in 2002 and selected farmers from all the ten regions of Ghana participated. Thereafter, many farmers established mulberry farms and begun producing cocoons which were supplied to CSIR-IIR for processing. As part of implementation of the Sericulture and Silk Processing Developmentproject, the Sericulture Promotion and Development Association of Ghana assisted in the selection of 10 small scale pilot farms located in strategic districts of Ghana where sericulture activities were common. These pilot farms were supplied with a full complement of rearing tools and equipment and served as centers where other farmers went for information, advice, as well as planting materials for the establishment of new farms. Over 300 farmers were trained in general sericulture and cocoon production as part of the project implementation plan. The project also led to the installation and test run of the Silk Production and Demonstration factory at the Institute of Industrial Research in July 2004.

Ghana has a huge potential for silk production, however, challenges in the areas of infrastructure, inputs and technical expertise at various levels of the production chain is a threat to this potential. For sustainable and quality production of silk and silk products, there is a need for the mastery of cocoon production skills. This can only be attained through continuous monitoring of the quality as the industry grows. While countries such as China and India have been practicing sericulture for several centuries, Ghana is in its tenth year of formal introduction of sericulture into the country but will have to produce to meet existing standards in the world market if any impart is to be made in the long run.

The raw material for silk production is cocoons. A cocoon is a protective shell made up of a continuous long protein silk filament spun by an adult silkworm. 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 [6]. Quality of raw material, reeling machinery, reeling process parameters, human skill involved in manual and mechanical operations and quality of water are the major factors that have direct bearing on the productivity and quality of raw silk. Among these, quality of cocoons plays a major role on raw silk yield and productivity.As cocoon quality contributes to the tune of about 80% of the raw silk quality, good quality cocoon is essential for the production of quality silk. The quality of silk cocoons depends on many characteristics and each of these measures different aspects of quality of cocoons [7].

The quality of cocoons also depends on various rearing techniques adopted by the farmers. Besides inherited characteristics such as colour and shape, many variable characteristics such as weight of cocoons, length, width, weight of cocoon shell, size, shape and filament length among others depend greatly on the rearing techniques and the environmental conditions during the rearing period.

The most significant commercial feature of cocoons is weight. Cocoons are sold in the marketplace based on weight as this index signals the approximate quantity of raw silk that can be reeled. The whole weight of a single cocoon is influenced by silkworm species, rearing season and harvest conditions [8].Cocoon weight and shell weight are the important or main traits evaluated for productivity in sericulture and these characters have been used for breeding more than half a century [9]. Further, weight is also influenced by the type of technology used for rearing and mounting [8].

Shell ratio which is the ratio of weight of cocoon shell to weight of the whole cocoon gives a satisfactory indication of the amount of raw silk that can be reeled from a given quantity of fresh cocoons. The calculation assists in estimating the raw silk yield of the cocoon and in deriving an appropriate price for the cocoons. This ratio varies depending on the breed of the silkworms, rearing and mounting conditions.

The shape of cocoons like color is a key characteristic of the species and is used to identify the variety of species and also reelability. It can be affected by the mounting process during production especially during the cocoon spinning stage. Significant variation in cocoon shape and cocoon size in hybrids results in variation in filament size as well as the quality of the reeled thread [10].

[11]Also mentioned that when reeling is carried out with irregular and non-uniform cocoons it results in thread breakage, hindrance due to slugs, poor reelability, poor cooking, decreased raw silk recovery, variation in raw silk denier and poor neatness. According to [12], cocoon size uniformity is very important to obtain uniform filament size in auto and semiautomatic reeling units. Rearing techniques such as density of mounting and care after mounting and time of harvesting cocoons may vary from one farm to another.

Thisstudy aimed at determiningwhether there is a significant variation in the physical properties of cocoons produced by ten different farmers.These farmers had received the same form and level of training and inputs for mulberry cocoon production. Since cocoons are a key raw material for the production of silk, variability in the characteristics of cocoons from one farm to another will help determine implications for silk production in Ghana and the next steps.

II. Materials and Methods

The cocoons used in this study were sampled in March 2014 from consignments received at the Pilot Cocoon Processing Factory at CSIR Institute of Industrial

Research from ten different farms in Ghana.The farms were selected based on a three year production history that guaranteed consistency of production over the period.

Fifty cocoons were randomly picked from cocoon consignments supplied to the factory from each of the selected farms andhot air dried in a batch type hot air drier with an initial drying temperature of 115ºC which was then lowered in stages every one hour to 100 ºC, 85 ºC, 70 ºC and 55 ºC with a total drying time of 5 hours.

A number of primary parameters of each cocoon were determined. These parameters include, dry cocoon weight, cocoon shell weight, pupae weight, cocoon length, and cocoon width. The longest axis of a cocoon was taken as length, while the width was measured at the widest section of the cocoon perpendicular to its length [13]. Measurements of length and width were taken with a digital vernier caliper accurate to 0.01mm while mass was measured using an electronic balance accurate to 0.001 gm.

Percentage Length towidth ratio was computed using the formula:

$$CocoonLength\ to\ WidthRatio = \frac{CocoonLength}{Cocoonwidth} \times 100$$

This ratio was analyzed statistically for standard deviation (SD) and coefficient of variation (CV). Cocoons possessing low standard deviation (SD) and coefficient variation (CV) values were considered uniform in cocoon shape.

The cocoons were cut with a sharp blade to retrieve the pupae which were weighed.The cocoon shell weight is calculated from the dry cocoon weight if the enclosed pupa is subtracted. It is the most sequential factor of quantity of raw silk that can be reeled. About 80% of this quantity is available for reeling [14]. Cocoon shell ratio is used to estimate raw silk yield of the cocoons and is therefore linked to the pricing of cocoons. Nonetheless, it is dependent on the rearing and mounting conditions. Other secondary parameters such as cocoon shell ratio and shape were also computed from the primary parameters.
Cocoon shell ratio was computed from the relationship

$$ShellRatio = \frac{Weightofthecocoonshell}{Weightofthewholecocoon} \times 100$$

The collected data were submitted to ANOVA test together with Simple regressions of cocoon length, cocoon width and mass with the null hypothesis that there is no difference in the characteristics of the cocoons from the various farms.For a posteriori comparison, the Bonferroni test was applied. Variability of cocoon size from one farm to another was determined by computing the standard deviation and co-efficient of variation as proposed by [12].

III. Results and Discussion

Tables 1 to 8 show cocoon weight and size characteristics as well as ANOVA results conducted on the various characteristics from the ten (10) farms.

Table 1: Cocoon weight characteristics of the ten (10) farms

Farm	**Dry Cocoon Weight (gm)**		**Pupae Weight (gm)**		**Shell Weight (gm)**		**Cocoon-Shell Ratio (%)**	
	Mean	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Oppong	0.378	0.107	0.133	0.067	0.245	0.058	66.5	11.4
Amartey	0.379	0.098	0.136	0.048	0.242	0.073	63.7	10.6
Helix	0.389	0.089	0.141	0.056	0.248	0.062	64.3	12.5
Kyeremeh	0.395	0.089	0.140	0.059	0.256	0.061	65.5	13.0
Senyo	0.377	0.098	0.130	0.053	0.247	0.068	65.8	10.9
Mampong	0.393	0.072	0.149	0.054	0.245	0.063	62.3	12.1
Goldstar	0.388	0.089	0.131	0.073	0.256	0.075	67.0	17.1
Agbozo	0.380	0.083	0.139	0.049	0.241	0.055	64.0	10.0
G S Addo	0.387	0.061	0.133	0.049	0.254	0.044	66.4	10.9
Samsam	0.385	0.102	0.128	0.057	0.257	0.092	66.2	14.3

From table 1, Cocoons produced by Kyeremeh farms had the highest dry cocoon weight of 0.395 ± 0.089 gm and Senyo farms had the least weight of 0.377 ± 0.098 gm.

The highest pupae weight of 0.149 ± 0.054 gm was however obtained from Mampong farms with the lowest pupae weight of 0.128 ± 0.057 gm was obtained from Samsam farms.

The shell weight ranged between 0. 241 ± 0.055 gm for Agbozo farms and 0.257 ± 0.092 gm for Samsamfarms.Cocoon shell ratio varied from 62.3± 12.1 at Mampong farms to 66.5± 11.4 at Oppong farms.

The ANOVA test results as shown in tables 2 to table 4indicate that there is no statistically significant difference in the weight characteristics of cocoons produced from all the 10 farms. At 95% confidence interval, Dry cocoon weight $F = 0.2680$; $p < 0.98$. Pupae weight $F = 0.5947$; $P < 0.80$; Shell weight $F = 0.4286$; $P < 0.92$; Tables 5 to table 7 show Cocoon size variables of length, width and length to width ratio and ANOVA test results conducted on these size variables. No statistically significant difference was found among the variables from all the ten (10) farms; however cocoon length varied between 1.81 cm to 3.41 cm, while the width ranged between 1.29 cm and 2.93 cm and cocoon length to width ration was between 105 and 215. Cocoon length $F = 1.876$; $P < 0.053$; Cocoon width $F = 1.500$; $P < 0.14$; Cocoon Length/Width ratio $F = 1.837$, $p < 0.06$

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Table 2: Results of ANOVA statistical test performed on Cocoon Weight

Source of Variation	Sum of Squares	df	Mean Squares	F
Between	1.9453E-02	9	2.1615E-03	0.2680
Error	3.952	490	8.0659E-03	
Total	3.972	499		
The probability of this result assuming the null hypothesis is 0.98				

Table 3: Results of ANOVA statistical test performed on Pupae Weight

Source of Variation	Sum of Squares	df	Mean Squares	F
Between	1.7449E-02	9	1.9387E-03	0.5947
Error	1.597	490	3.2599E-03	
Total	1.615	499		
The probability of this result assuming the null hypothesis is 0.80				

Table 4: Results of ANOVA statistical test performed on Shell Weight

Source of Variation	Sum of Squares	df	Mean Squares	F
Between	1.6910E-02	9	1.8789E-03	0.4286
Error	2.148	490	4.3834E-03	
Total	2.165	499		
The probability of this result assuming the null hypothesis is 0.92				

Table 5: Results of ANOVA statistical test performed on Length

Source of Variation	Sum of Squares	df	Mean Squares	F
Between	0.6483	9	7.2029E-02	1.876
Error	18.81	490	3.8389E-02	
Total	19.46	499		
The probability of this result assuming the null hypothesis is 0.053				

Table 6: Results of ANOVA statistical test performed on Width

Source of Variation	Sum of Squares	df	Mean Squares	F
Between	0.2109	9	2.3429E-02	1.500
Error	7.654	490	1.5621E-02	
Total	7.865	499		
The probability of this result assuming the null hypothesis is 0.14				

Table 7: Results of ANOVA statistical test performed on Length/Width ratio

Source of Variation	Sum of Squares	df	Mean Squares	F
Between	3165	9	351.7	1.837
Error	9.3825E+04	490	191.5	
Total	9.6989E+04	499		
The probability of this result assuming the null hypothesis is 0.060				

Table 8: Cocoon size variables of the ten (10) farms

Farm	Cocoon Length		Cocoon Width		Cocoon Index (100 x Length/Width)		
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	CV
Oppong	2.849	0.291	1.670	0.231	172.39	20.6	11.98
Amartey	2.916	0.068	1.678	0.071	174.09	7.97	4.58
Helix	2.961	0.120	1.670	0.058	177.41	8.02	4.52
Kyeremeh	2.987	0.137	1.671	0.053	178.81	7.98	4.46
Senyo	2.943	0.207	1.646	0.161	179.90	16.1	8.93
Mampong	2.922	0.064	1.633	0.060	179.18	7.90	4.41
Goldstar	2.948	0.194	1.710	0.133	172.97	13.00	7.53
Agbozo	2.937	0.273	1.657	0.111	177.98	19.6	11.01
G S Addo	2.961	0.169	1.671	0.094	177.57	11.6	6.54
Samsam	2.965	0.273	1.690	0.152	176.18	17.0	9.64

From table 8, variation in the size of cocoons from the ten farms showed that the mean cocoon index ranged from 172.39 (Oppong farms) to 179.90 (Senyo farms). The lowest standard deviation of 7.90 was recorded from Mampong farms and the highest of 20.6 was for Oppong farms. The coefficient of variation on the the cocoon indices from the ten farms ranged between 4.41 (Mampong farms) to 11.98 (Oppong farms).

The characteristic upon which the quality of cocoons is based depends not only on the species but also on the execution of the mounting process during production. Thus even though the shape of cocoons is heritable, it is affected in part by the mounting process. Variation in cocoon indices is an indication of variation in shape of cocoons of which may have been influenced by the level of skills employed especially during the mounting stages of the cocoon production process. It may therefore be deduced that the type of mountages and care taken during cocoon spinning may have varied from one farm to another.

Farms with cocoons having less cocoon size variability represented by computed cocoon indices is a pointer towards more uniformity of cocoon shape and size which are key parameters for determining silk yarn quality. According to [12] Mano (1994), cocoon size uniformity is important and necessary in the use of auto and semi-automated machines for reeling silk cocoons.

IV. Conclusion

On the basis of standard deviation for cocoon indices of 8 or less with minimal co-efficient of variation (CV), four farms Mampong (Cocoon Index of 7.90 and co-efficient of variation 4.41), Amartey (Cocoon Index of 7.97 and co-efficient of variation 4.58), Kyeremeh (Cocoon Index of 7.98 and co-efficient of variation 4.46) and possibly Helix farms (Cocoon Index of 8.02 and co-efficient of variation 4.52)produced cocoons that are uniform in shape. This notwithstanding, there is no significant differences in the physical characteristics of cocoons produced by mulberry cocoon farmers in Ghana.

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Authors Profile

J. Amoah
is a Ghanaian resident in Accra. He holds an Msc. Agricultural Engineering degree from Wageningen Agricultural University in the Netherlands. He is currently working as a Senior Research Scientist with CSIR-Institute of Industrial Research and is also the Factory Manager of a pilot Silk Production and Demonstration factory at CSIR-Institute of Industrial Research in Accra. He teaches on part-time basis Postharvest related courses at the undergraduate level at the Department of Agricultural Engineering, University of Ghana Legon. His area of specialization is Postharvest Machinery Systems Design and Management.

K. Akufo-Kumi
is a Ghanaian resident in Accra. He holds a Master of Philosophy degree in Physics from the University of Ghana, Legon. He is currently working as a Senior Research Scientist with CSIR-Institute of Industrial Research and is also the assistant Laboratory Manager of the Regional Testing & Knowledge Centre (RTKC) for cookstoves. He supervises the laboratory project works of graduates and undergraduate students.

W. O. Oduro
is a Ghanaian resident in Accra. He holds a DPhil. Inorganic Chemistry degree from University of Oxford, UK and currently works as a Research Scientist with CSIR-Institute of Industrial Research. He has a passion for sustainable development and is presently engaged in research developing greener technologies.

M. A. B. Animpong
is a resident in Tema and holds an MSc. Physics (Materials Science) from Kwame Nkrumah University of Science and Technology, Ghana. She is currently a research Scientist with the CSIR- Institute of Industrial Research, Accra, Ghana. Her area of specialization is in Natural and Synthetic Materials Development.