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〈特別寄稿〉

Overall Discussions and Conclusions of the Silk Studies (60th Birth Memorial Report)

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絹絲硏究의 綜合的 考察과 結論

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I. Forward description

Since thousands of years ago, silk has been treasured as much as diamond and pearl. It is because silk has its unique aroma which no man made fiber can equal to.

People in any part of the world can not enjoy a really rich living or a bright frame of mind without wearing silk. This means the silk is only silk.

Mystery of silk and mysterious quality of silk come from the fact that it is a protein fiber produced by the living insect, namely, the silkworm.

Cocoon filament spun by the silkworm is so fine, about twenty microns, that 100 filaments put together has a diameter of no more than two milimeters. And yet, a cocoon filament is an assembly of many finer fibers. If magnified many times, silk would reveal many sticks bandled together, while man made fiber would look like a piece of rod.

Such construction of silk made up of minute fiber can never be imitated by artificial fibers but is a source of its mysterious quality.

The lustre of silk is exquisite. It is not of metalic gimcrack. Why? Because silk is an assembly of many, very minute fiber as mentioned above, light coming up from the inside and that from the surface interfere each other to shed a peculiar lustre. The beautiful lustre, the gist of pearl is caused by the interference of light, just like the case of silk. Although pearl looks like a round bead, it is, if analyzed, made up of many layers of protein, which causes lights reflected from various layers interfere with each other. In man made fiber, light is reflected, but never led to interfere. To wear silk, therefore, equal to wearing pearl in its best in the matter of lustre.

Silk is very beautiful and vivid in color and pattern, as silk can be dyed with any kinds of dyestuff. Designers through out the world patronize silk for its color and pattern which can never be imitated by any other textile. Once people wear silk,they cannot forget its soft, elegant touch. Silk can closely fit the body, producing a chic silhouette, as it has a high drape.

Now, what is the silkworm then? According to the classification given by Bock and Pigorini(1938), the silk spinning moths belong mostly to the family *Bombycidae*, which consist of subfamilies *Bombycinae*, *Saturniinae* and *Thaumethopoeinae*. The most important species commercially is *Bombyx mori*, a member of the *Bombycinae* subfamily. Although this moth is a native of China, it has been introduced into many countries. The large and beautiful moths of ths *Saturniinae* subfamily produce the wild silks of commerce. *Antheraea* is the most important species, and tussah silk is obtained from *Antheraea pernyi*, a native of Mongolia, and from *Antheraea mylitta*, found in India. *Attacus ricini* is also important species, and eri silk is obtained from this, native of India. The *Anaphe* species, found in Africa, is one of the most important of the subfamily *Thaumetop-*

oeinae. These silkworm build very large communal cocoons, often containing several hundred of the insects. The reeling of these cocoons has not so far proved commercially profitable, partly because of their complex structure and partly because they are contaminated with large amounts of debris of all kinds.

When we look over the historical review on sericultural science or technique, they may be summarized as genetical breeding services and physical studies rather than chemical aspect except some biochemical activities. Another word, a kind of traditional studies have been continued for many years in the sericultural world societies, while synthetic fibres have been developed on the other hand.

Of course such a researching trend cound not bring any remarkable transition for the progress of sericultural science. Silkworm has been handled from the aspects of phisiology, anatomy, pathology and biochemistry for many years, but it was not concerned with applied chemistry or medical science. If any medical care be available for silkworm diseases, that will be a great contribution for the progress. At present, only disinfecting services are carried out for the silkworm hygiene. After all, the environmental control such as temperture and humidity have been the most important matter for silkworm rearing service.

When we think over the environmental control factors for biological world, there would be many items to be classified as followings.

(1) Physical control
   - a, temperature and humidity control
   - b, filtering control
   - c, ventiration control
   - d, radio active power control

(2) Chemical control
   - a, polution control
   - b, aerobe microbiological control
   - c, hygienic control
   - d, sterilizing control
   - e, filtering control
   - f. anesthesis control
   - g, smell control
   - h, insecticing control

In case of consider the silkworm, we used to concern with only a few matters, like as, temperature and humidity or sterilizing control among the listed items. So, the author has decided to open his eye more broadly over for many possible controlling methods so that he may find any better result by using such various controls. For instance, we are suffering with air polution or radio active power, but we can apply this matter for some benefit by timing control like as radio active radiation for medical services.

After establishment of his working line in such way, he has started to change air condition where silkworms be kept in such an artificially controlled environment. Such trial may be possible by the progress of vinyl cover industry because the vinyl cover may discreminate some limited air without trouble.

Through such efforts, he could made reports on

(1) Studies on silkworm selection by use of anesthetic (1973).

(2) The comparative studies of hatched silkworm dorminance seperation against sex seperation to meet silk promotion(1973),

He believes that he has established remarkable transition for sericultural science and may call attension to other workers. These two works are proposed under practical utilization by the concerned organization. He is not going to satisfy with the above reports, but he is trying to use such chemical air control for silkworm pupa or egg to change its voltinism and also silkworm diet to change wild plant lief flavor so that be able to use it for silkworm diet.

On the other hand, the author has continued his effort to establish Korean style silk process. These reports were written in Korean language because they are not concerned with world wide subject.

The author feels his responsibility that he has to work not only for the progress of world wide sericultural science, but also he should work how to keep the sericultural industry in Korea for future. No body denies that the Korean sericultural industry is under peak cultural condition in the world from production density aspect, but such peak condition may pass over to other country soon or later. There are serious compeditable industries in Korea which may bring about labor cost problem. If we satisfy with the

traditional techique, this will end with sooner discard of sericulture from this country. For instance,mulberry can be cultivated during all the year round in semi tropical countries where they can rear silkworms for several times per year.

This thesis is discussed with the works more than sixty theses carried out by the author for the purpose of evaluation of his works. The thesis will be related as a overall conclusion for future to bring more effective result. Sixty two works concerned with this subject are listed on this report.

II. Part of basic science

1. Numbers of amino acid residues on silk fibroin.

As long ago as 1865, Cramer showed that a mixture of amino acids is formed when *B. mori* fibroin is hydrolized, and he identified glycine, tyrosine, and leucine. By the efforts of a number of workers, notably Fischer and his workers, a qualitative picture of the composition of silk fibroin in terms of amino acids was gradually constructed. The early work in the field, including the techniques used, has been summerized by Howitt(1946), more recent developments in analytical technique have been described by Stein and Moore(1948), Tristram(1949), and Moore and Stein(1951). We'll here discuss the later analytical results without entering into descriptions of the methods by which they were obtained. It is generally agreed that fibroin is composed of long polypeptide chains. Fibroin is usually considered to be a simple protein; nevertheless, it contains at least 17 different kinds of amino acid residues, with glycine, alanine, serine, and tyrosine predominating. Beside of the above amino acids, the author(1962) has found two more amino acids in the silk fibroin, that is, cystine and hydroxyproline. Even though these amino acids are found as very small amount, the existence of cystine had brought a new look on silk fibroin structure because it can be found as only crosslinkage on the silk peptide.The former acid was analyzed by other workers following after the author's report, but hydroxyproline is still concerned as private report (1965). Now, 18 different amino acid residues are recognized in the world science, but the author still believes that there would be no limitation on the number of amino acids as eighteen kinds, and may be found more than that.

Other analyses frequently show considerable variations even for the major constituents. These differences may be attributed partly to experimental error, but it is also possible that they represent genuine differences in composition resulting from varying diet and breeding localities of the silkworm. The author (1964) has found that the fact can be found by the difference of silkworm variety and also he has found the different composition between parents cocoon silk and their hybrid cocoon silk fibroin which was considered to be genetical influence for the biological synthesis.

2. Sequence of amino acid residues

We will discuss the arrangement of amino acid residues in the fibroin molecule, a subject which is of importance in connection with X-ray studies on fibroin The only published data relate to *B. mori* fibroin. and the available information has been obtained by identification of the peptides resulting from partial hydrolysis of the protein under various conditions. The peptides Gly·Ala, Ala·Gly and Gly·Tyr were isolated and identified in early work(1907). Abderhalden and his coworkers subsequently identified a number of larger peptides in the hydrolyzates, viz. Gly·Ser·Pro·Tyr·Pro, Ser·Pro·Tyr·Pro(1932), and Tyr·Ser·Pro·Tyr(1933). Sanger(1952) has pointed out that although the charcaterization of these peptides is not absolutely certain, the results at least show that tetrapeptide sequences containing no glycine occur in fibroin.

The relative yield of dipeptides Gly·Ala and Ala·Gly in fibroin hydrolyzates is important since it has a bearing upon the existence of long runs in which glycine and alanine residues alternate. If such runs do in fact exist, the yields of the two peptides might be equal. Synge(1945) has shown that the dipeptides Gly·Ala and Ala·Gly are hydrolyzed at the same rate and this might apply to the higher peptides.

These results show that long chains with alternating residues of glycine and alanine are not important constituents of fibroin. It was calculated that for a

purely random arrangement of residues, the maximun yield of Gly·Gly would be 18.8% and that of Gly·Ala or Ala·Gly to be 12.4%. The high yield of Ala·Gly indicates that the arrangement is not completely random. Further, the low yield of Gly·Gly suggests that there are no extensive sequences of glycine residues in silk. Levy and Slobodian have remarked that their results are consistent with a minimum repeating unit of the type X·Ala·Gly·Ala·Gly·X·Gly where X is any residue other than glycine or alanine. If sequence occurs frequently in the fibroin chain, the yield of Ala·Gly should be twice that of Gly·Ala according to Levy and Slobodian. The experimental findings are consistent with this. Further, the isolation of large proportions of Gly·Ala·Gly from fibroin hydrolyzates by Slobodian and Levy (1952) appears to support the idea of the frequent repeatition of the postulated sequence. However, the fibroin chains can not have the simple structure represented by (X·Ala·Gly·Ala·Gly·X·Gly)n. Such a constitution would not account for the tetrapeptides containing no glycine or alanine, isolated by Abderhalden and Bahan, or for the results of enzymatic hydrolysis.

A more detailed chromatographic analysis of the peptides present in partial hydrolyzates of silk fibroin has been carried out by Kay and Schroeder(1954). In the main theses, they confirm the results of Levy and Slobodian, but criticize their interpretation. Thus, for example, Kay and Schroeder pointed out that the isolation by them of significant quantity of Ala·Ala cannot be accounted for it that fibroin has the structure (X·Ala·Gly·Ala·Gly·X·Gly)n. Further they suggest that the relative rates of hydrolysis of the bonds X·Ala and Gly·X might affect the yieids of Ala·Gly and Gly·Ala. The conclusion of Kay and Schroeder is that "at the present state of our knowledge, one can draw few definite conclusions about the studies of partial acid hydrolysis."

In case of use the knowledge of DNA and RNA on the sequence of amino acid residues, there will be more complicated discussion. As far as the silk protein is synthesized in the silkworm, we can not stay out from such an aspect. In generally, the biological synthesis of protein is explained by either stepwise mechanism or template system. In which the template theory has related with RNA and DNA. The genetic code which is nucleotide sequence, is translated into amino acid sequence of protein synthesis. Since that specific proteins not only from many of the structural celluar components, but more importantly, control as enzymes most of biosynthetic and metabolic events in living cells. The nucleotide composition of DNA and RNA are proved to the basic information site presiding the specific biochemical events and structures of living silkgland. In order to apply such a knowledge into the synthesis of silk fibroin, the author(1963) and his coworkers have contributed to search the RNA behavior during the growth of silkworm egg stage where the RNA content variation has close relation with the development of the silkworm embryo and they(1966) analyzed also the base of DNA from the extraction of silkworm testis where they have found the(A+T)/(G+C) ratio, which is similar to other insects, like grasshoppers. The author believes that the work has been started as the first trial in this field in 1963. Then some other workers have joined in the field later on.

The analytical results of the authors report on the amino acid composition regarded with the parent and the hybrid silk(1964) showed that the fibroin synthesis is fairly related with some genetical factor or template system, but it would be dangerous to support it perfectly.

On the other hand, silkworm formation is believed to be governed not only by the genetical factor but also by the independent individuality.

As far as the specific nucleotide sequence of DNA and RNA of the sikgland is not clear to make synthetic silk, there would be no any conclusion about it, and such a problem will lie as very difficult work for a long time.

3. Fibroin structure

Most of our knowledge of the structure of silk has been obtained from X-ray and infrared studies on *B. mori* fibroin. The first observation of the X-ray diffraction pattern was made by Herzog and Jancke (1920), the fiber axis identifying period was given as 7 angstroms by Brill (1923), and the first inter-

pretation of the diffraction pattern in terms of polypeptides chains is due to Meyer-Mark (1928). This early work was followed by the investigations of Kratky and Kuriyama and others, which established the rough outlines of the structure of the crystalline portions of fibroin. It is now accepted that these consist of sheets of extended polypeptide chains together by hydrogen bonds between the >CO and >NH groups of neighboring chains, the inter sheet forces are of the Van der Waal's type. The fact that fibroin has sheetlike structure is indicated by the production of double orientation by rolling and the structure proposed consists of antiparallel chain pleated sheet as shown by Herzog and Jancke(1929). Fibroin is, therefore, a β-protein. Determination of the detailed structure of fibroin encounters all the difficulties described in specific literature.

The nature of the amino acid residues present in the crystalline portions of fibroin has been a matter of doubt since the earliest X-ray observations. Since the unit cell is rather small, it has been generally believed that the crystalline regions are composed of glycine and alanine residues, with serine occasionally replacing alanine. The presence of larger residues, such as tyrosine and arginine, has been considered very improbable. Brill(1943), for example, has concluded definitely that there is no sufficient room in the unit cell for the benzene nucleus of tyrosine.

There was, however, no way to explain how the presence of larger residues related with the silk peptides. These problems have brought to consider the crystalline portion and amorphous portion in the silk fiber, which the latter may composed of such a larger residues in its portion. The author(1962) has happened to identified such a portion both crystalline and amorphous in 1962, so, there would be no doubt that the silk fibroin has two different portions in its structure. Especially the newly found cystine is deemed to be located in the amorphous portion of silk protein

III. Part of preparation of silk cocoon

The silk spinning insects have to eat their suitable diet during their larvae stage to grow to be the matured insects to spin out the silk filament for preparation of cocoon.

The diet for such a worm must be involved with attractive factor, swallowing factor, and biting factor with in it. For instance, mulberry leaf is the only diet for the *Bombyx mori* worm, while oak tree leaf and the relative leaves are for *Antheraea* worm, and caster tree leaf and the relative leaves are available for *Attacus* worm.

1. Silkworm diet

We shall discuss various items raised on this section both in academic and technical aspects, because we are going to concern with the productivity of the related matter with cocoon.

Mulberry leaf is the only available diet for *Bombyx mori* worm at present, even though some people have been tried to develop an artificial diet for it. This fact means that the preparation of mulberry field is the preparation of silk cocoon, so, there would need wide fertilized land to produce mulberry or cocoon. The detailed culturing technique and labour problems will leave out on this paper, but we shall concern with the nutritive discussion of the mulberry. The author(1962) has analized the chemical composition of various varieties of mulberry leaves cultured in Korea and compared the nutritive values contained in it, which has been widely used the result on the interpretation of mulberry quality.

From a nutritional point of view, there are many kinds of leaves which could feed the worm, but we have never succeeded in obtaining good results than mulberry leaves with those from other species of plants, because of its specific attractive factor.

Biochemically, it is very natural that the mulberry leaves should contain all kinds of nutritive matters not only tryptophan but also cystine or cysteine, so, should be methionine either. Therefore, it is natural that whole silkworm life cycle processes should be concerned more or less with cystine. However, no paper has made concerning report on the matter before the author's work (1962).

The proteins included in mulberry leaves were assumed to be globular-netting form or globular form depending on the kinds of protein, any how, the au-

thor found that these proteins are not linear peptide form like as silk fibroin.

No body denies that the Korean sericultural industry is under peak cultural condition in the world from production density of view, but such peak condition may pass over to other country soon or later. There are serious compeditable industries in Korea which may bring about labor cost problem. If we satisfy with the traditional techique, this will end with sooner discard of sericulture from this country. For instance, mulberry can be cultivated during all year round in semi tropical countries where they can rear silkworms for several times per year.

After the author visited to the United Arab Republic(1969), Thailand(1972), India(1974) and Philippines (1976), he has found that those countries have much better advantage to work with sericulture.

These countries need not worry silkworm diet available in any case through the year. Korea is, however, needed to develop silkworm diet to compete with such countries which is economically available. Unfortunately, the works on artificial silkworm diet in the past are evaluated as too expensive and very far away from the practical use at the moment. The development of some economical diet should be carried out which should be started with other direction from the past work lines. Chemical air control method may be replaced with such a slump situation.

It is generally understood that a normal silkworm eats about 20 grams of fresh mulberry leaves during its larva stage which corresponds to about 6.0 grams in dry weight or to about 1.8g of protein.

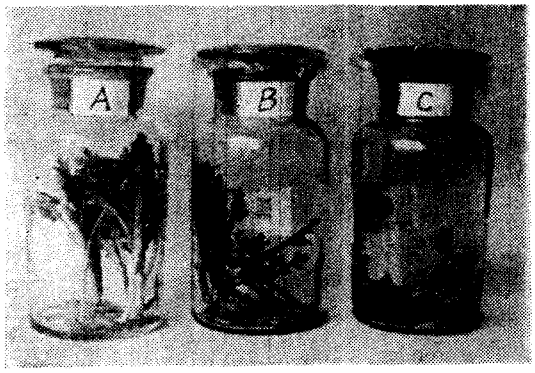

Fig. 1. Example of anesthesis control on plant
A; —blank control B, C; —treat in step

When we consider the amino acid composition of the mulberry protein(1 or 2% for every acid), it is easy to imagine that there must be intensive amino acid transformation in the silkworm to make silk protein.

Now, let us discuss the mulberry field standing upon from economical aspect. It generally understood that the best annual silk production per hectare of mulberry field is about 100kg at most. This means that there would be necessary tremendous mulberry farm area to produced reasonable silk as industry scale. More over, the necessary labour expenses have been raised in recent years. When we think over the increase of human population, there will be serious food problem sooner or later which the mulberry farm must be replaced with food production.

In order to solve the diet problem before we meet with such a danger, the author(1968) happened to be interested in the wild silk worms like as tussah and eri which can eat wild plant leaves easily growable on hillside.

Other method for the problem is to develop some artificial diet for silkworm in industry scale. The author(1966) had tried to join in such an work, but the result was not satisfactory at present.

2. Cocoon preparation

Majority of silk cocoons are produced as commercial purpose, using the hybrid from the different varieties of silkworm bred from genetical aspect. That is why, breeding work is the most important process to get better cocoon or silk yield.

There are fairly complicated routine for the slecting process during the breeding work and it takes many years to make one satisfactory variety of silkworm.

In order to save the time for the selection of silkworm during the breeding work, the author (1971) had tried to use ethyl alchol vapor by which silkworms are narcotized and when they are removed out in fresh air, the stronger worm is, the earlier recovers from its narcosis and starts to eat mulberry leaves. Such a method is found as an innovative and more scientifical method than the traditional work carried out before.

The silkworm rearing method either breeding or

commercial purposes do not different much, so, the discussion is not necessary here. But, we will concern with the cocoon filament spinning mechanism, because it is important to know the variation of cocoon filament size. The viscous liquid in the gland of *Bombyx mori* worm which silk filaments are spun, is generally believed to be an aqeous solution of fibroin and sericin. The work of Yamanouchi (1921), which has recently been confirmed by Mercer (1954), shows that the two proteins are distinct and separate in the gland, the sericin enveloping the fibroin core. During spinning, a pair of fibroin filament extracted from two spinnerets become coated and gummed together by sericin, as already mentioned. Whether the sericin plays any fundermental part in the actual spinning operation, distinct from its adhesive action in holding the cocoon together, is not known.

Eventually, the spun silk from the spinnerets is not uniform in its size, it is spun with rather coaser size but gradually ends with finer filament. Such a irregularity of the cocoon filament causes the size deviation of raw silk made by them. The author (1962) has established a relationship between cocoon filament size deviation and raw silk size deviation, and the inevitable reason of the irregular spinning by the worm are studied in anatomical respect. After all, the author has shown the estimate raw silk size deviation from the inspection of cocoon filament size.

On the other hand, the general qualities of cocoons influence greatly for making silk fibers out of them. Specially, there are many abnormal cocoons produced by farmers in Korea, and causes the bottle neck for the silk production mechanism both in silk quality and yield or working efficiency. The author (1971) has investigated how much the abonormal cocoons cause damage on the silk production, so, he recommended (1976) to raise silkworms more carefully and to take care of proper cocoon mounting service to make more uniform cocoons by farmers.

IV. Part of raw silk producing process

The raw silk producing process is composed of

(1) Cocoon drying process(Related paper, 1 subject)

(2) Cocoon cooking process(Related paper, 3 subjects)

(3) Silk reeling process(Related paper, 6 subjects)

(4) Silk finishing process(Related paper, 1 subject)

The silk reeling is carried on various machines for the purposes, but the author has tried to promote the silk production based on various chemical treatments instead of the remodeling the processing machine. The change of such machines are rather difficult to make, because of need much expense and there is no much demand for purchasing those new machines to be sold in Korea.

During the process cocoon for silk production, water and heat are used on the cocoon beside the machines applied on. The heat and water act on the cocoon sericin to be denatured. Other problem to be considered is that there are mixed cocoons different each other of individual cocoon nature, so, it is very difficult to process with a machine in proper way.

1. Cocoon drying process

After fresh cocoons are dried in proper degree,the dried cocoons are usually put into cotton bag every 50kg each. When these bags are stored in a store room, the dried cocoons begin to absorb moisture in the air and cause to denature the cocoon sericin and damage the silk reelability during the silk reeling process.

From such a reason, the author(1966) has tried to use polyethylene bag instead of cotton in order to cut out the moisture absorption of the dried cocoon.

The author has found that there was no difference of cocoon weight by room humictity variation, but he has also found unexpectable result of fogy air in the bag when temperature droped down during winter and the saturated air caused damage on the cocoon inside, but it was very good in tropical area.

2. Cocoon cooking process

Korean cocoons were evaluated as rather poor quality on their reelability condition The author (1965) has tried to solve this problem by using chemical (Serisol) which was developed by him. The result for the use on this process was reliable, but he(1967) has found that the treatment is not uniform all over the cocoons because the chemical absorption is not uniform.

On the other hand, the author has succeeded to improve the cocoon reelability by using surface active agent(Seracol 100) which was developed by him and it has been used in silk factories of Korea. The author(1971) has worked out how the mineral components in the cocoon cooking water relates with the action of the surface active agent.

3. Silk reeling process

This process is the major work in silk reeling factory and the author has devoted his effort on this process either some theoretical studies or technical matters.

A theoretical or scientifical approach was carried out for the cocoon shape in the silk reeling bath and he(1958) has recommended that there would be no misunderstanding by looking at it.

Meantime, the author(1961) has also worked on the theoretical approach about the maximum reeling velocity(300m/min) and silk strain energy occured during the reeling process which are used by traditional experience of the work in the past.

For the technical studies on this process, the author (1961) tried to use protein soluble enzyme in silk reeling bath and chemicals in the tussah silk reeling bath. Specially, the tussah silk(1963) reeling is hardly to work with water alone, but needed some chemicals to add it. He was the first man to use chemical and reel the tussah cocoons in the reeling bath. Since then, the tussah silk reeling work has been developed satisfactorily by the development of Tussahlite for the cocoon cooking.

Since 1957, Korean silk factories have started to install automatic silk reeling machines and now 100% of factories operating with the machines at present. Korean cocoons, however, was found not proper for the machine, so, the author(1971, 1972) and his co workers have started to find more reasonable processing method by use of such a machine.

4. Raw silk finishing process

Several years ago, the moisture content of the finished raw silk has been considered as an important problem, because there was a trend to put moisture artificially in the silk skein in order to get a better winding test result on the silk testing service. As a result of such work, there happened to have fungous silk or sticky silk skeins on the commercial silk. The author(1965) has started to investigate on this problem where he has found the moderate moisture content on the silk skeins against their winding test.

Then there was no man to do such a foolish work since the report was published. Beside the above reports on the silk reeling work, the author has attended various technical seminars every year in this field and gave them advises in the technical problems.

As far as technical problems are concerned, Korean engineers have made long progress on the practical engineering work in recent years. There were many things that can be improved just by instant advises rather than written paper.

V. Part of raw silk testing

Because silk is used for high quality of textile, there are many items to test with silk yarn before moving into textile process.

For instance, silk lousiness has been considered as serious problem for harming on dyed textile and many workers have joined with the problem to solve the defect. The author(1963) has also worked on this for several years through out the fundamental origin of silk lousiness on anatomical respect, genetical respect, and improving chemical treatment and so on.

He has first classified the nature of silk lousiness as three different groups and established the lighting condition to observe it on silk textiles.

Such a lousiness is not only shown in silk textile, but also it appears in other textiles which did not care much on the normal textile in the past.

Then, the author(1964) has reached to a conclusion that there is only way to solve this problem by using chemical sericin softener on the silk refining process and work end with partial refining before silk split ends come out from it in the normal refining.

On the other hand, the cleanness defect of Korean silk has been considered as serious matter since several years ago. The author(1970) has investigated on the problem where he has found a close relationship

between neatness and cleanness, and the neatness is easily damaged during poor cocoon mounting work or poor handling of fresh cocoons which result with damage on cleanness. The cleanness defect has been understood as occuring problem only during the silk reeling process and never thought of it come from cocoon. This was a big misunderstanding in the past.

The author(1970) has investigated that the cocoon drying capacity, filature water quality, technical level, and type of the silk reeling machine have also concerned with the cleanness defect, by which he has derived a statistical influence of using those relating factors.

It is deemed that the report showed rather exact causes of cleanness defect in silk fiber and showed a direction to improve the defect.

As already mentioned in the previous section, the raw silk size deviation has been considered as an impor tant matter on the silk textile processing and its uniformity as clothes. The author(1967) has worked on this problem from the point of view anatomical respect and theoretical respect. He has found the minimum raw silk size deviation in case of using Korean cocoons and any more deviations above this are coming from the carelessness during the silk reeling process.

The author (1973) has also worked how the raw silk cohesion test result could be improved during the test through the silk reeling and finishing process.

The international raw silk grade classification method has been amended for several times since it has been created in 1932. Scuh rather periodical changes have been raised as problems not because of it was created by scientifical research background or academical base but because of rather commercial aspect.

The author(1981), however, discussed by thoroughful academical aspect regardless raw silk sailers or buyers commercial interest. After carring a theoretical approach with the relationship between raw silk grades and its textile grades, he happened to compare the current raw silk grade classification method against the developed theoretical silk grade classification method, which they are much different each other.

As all of us know, the present international raw silk grade classification table, specially for the major testing items, may be translated into as Figure 2 in case show the relationship between raw silk grade data and silk textile quality data. Another word, the poorer raw silk grade data has more wide interval than the better grade interval in case start out even interval of silk textile quality data.

According to this diagram, in spite of 2A grade of raw silk may produce fairly good grade of silk textile, the diagram shows it to be good for only 50 mark of silk textile which is not realistic from technical aspect. The diagram shows also that the higher grade of raw silk better than 3A could be made easily because the corresponded grade intervals are narrowed each other which are hardly understandful from technical aspect.

On the other hand, the theoreticaly derived classification table or its diagram shows the relationship like as Figure 3 which quitely different from Figure 1. According to this figure, it explains enough how difficult to make higher grade of raw silk to be match for best grade of silk textile. It also explains that the raw silk grade is easy to drop down to lower grade in case careless processing of silk reeling.

The above discussion was carried out that the raw silk testing service is processed in condition of random sampling and a normal-curve statistifical distribution for the test result. Japanese and this paper had found a secondary curve relationship for this matter by the same stand point. In case we deny such classification curve like as Figure 3 which happened to be a symmetrical diagram each other, straight line C is the case of non normal-curve test distribution like as Figure 4 or 5 (use for cocoon grading) which happened to be a center line of the above two curves.

In spite of start from the same foundation, we are seeing such difference between the current system and the developed system which is deemed to be the current system happened to apply their work result in wrong way. As far as curve A is located at the same side of the straight line C, regardless the form of curve, the grade interval system will not change to the grade intervals shown as Figure 5. That is why, the straight line C works as a sort of limit line for transform of the grade data interval system.

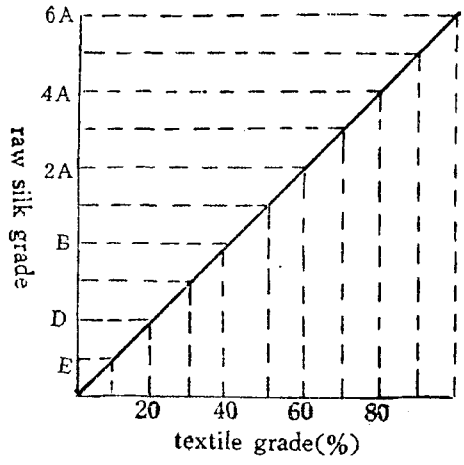

Fig. 2. Current raw silk classification diagram.

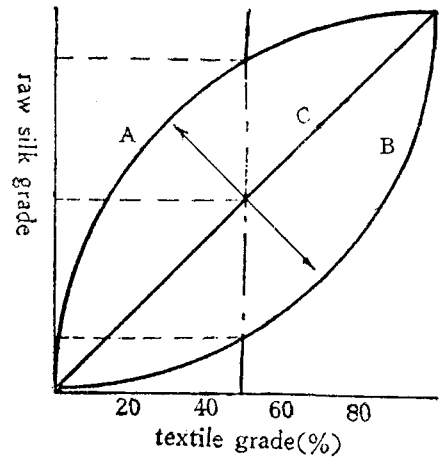

Fig. 3. Developed raw silk classification diagram.

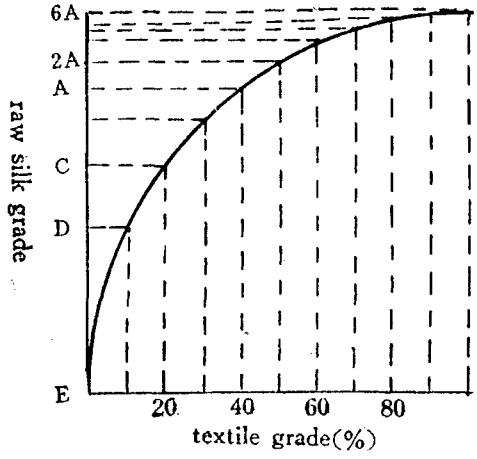

Fig. 4. Even interval grading diagram.

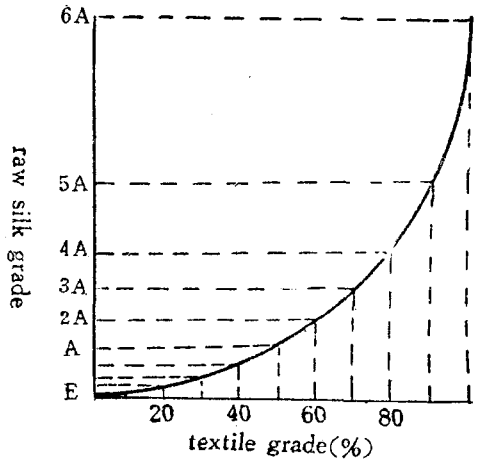

Fig. 5. Over lapped diagram of the three.

The more approach the curve to the limit line, the more grade data intervals will be uniform similar with Figure 4.

So far, as of the result,author(1981) recommended to Internationa Silk Association strongly that any future raw silk grade classification table should be corrected follow after the established principle of this paper so that the classification table may be matched with technical realities and end with more scientifi cal test method.

VI. Silk textile finishing

Silk textile finishing has been studied for many years by many workers in order to meet more utilities for various endusers. Such studies, however, could not be successful because any natural fibers are hardly change their natures by artificial treating methods.

Textile finishing is of course to improve the merchandise qualities and the poor natures of silk so that it may be available as the best textile fiber in the world. Sometimes, famous trade marked textile plays more power than its quality in the silk market, nevertheless, this should be over line of research activities. Meantime, the silk demand has been also transfered from ladies stocking to other clothes since nylon or other synthetic fibers were developed. That is why, the extension of silk demand should be developed by various research works.

Specially, silk is known as difficult textile to handle it during washing or ironing process which hap-

pened to depress down the silk use for house wives.

In order to solve such problems, the reporter has been worked for many years and, now, he believes that he(1981) has developed a proper finishing method to cover such problems. The developed finishing method may be said to eligible with economical aspect and shorten the dry duration after water washing in half against normal silk textile without harming the specific silk nature.

As all of us know, silk fiber starts to denature since it was spinned by silkworm and the fiber is formed as overlapped "S" type curves during its cocooning process, After it is made as raw silk or sericin silk, it shows as straight line form, but it changes in to waved form in case refining or degumming process in order return to its original spinned form. Such nature is continued during its textile form and ends with hard ironing nature than other textile fibers.

Other than his major study of silk textile finishing, he had carried out the following subjects.

(1) Urea resin treat effects on silk textile(1978).
(2) Urea resin graft finish on silk textile(1978).
(3) Studies on sericin fixation by use of alum meal (1979).
(4) Studies on sericin fixation(1980).
(5) Silk textile wash and wear finishing(1981).
(6) Wash and wear silk finishing collaborating anticrease (1982).

Normal silk fiber keeps to continue its denaturing and this is iniciated by repeat of washing and drying which takes many years to reach its final stage. The reporter(1981) has found the iniciating denature of silk by his finishing process, with out heating, decreasing the swollen nature which ended with shortening the drying duration after wash as follwings.

The decreased swelling nature has brought about the drying period in half against standard silk after all.

Not only the tests of tenacity and elongation but also crease recovery, stiffness and shrinkage tests were carried out after each washing which he has found good result on the treated silk textile against the standard silk. The most important thing was to keep the textile feeling of silk by such finishing work before improve any poor nature of silk.

The general silk has a nature to absorb smoke or dirt from its surrounding air and reaches to dirty color shade upon such exposure, but the treated one has improved such nature becauses of its artificial denaturing, another word, it keeps clean longer than the normal silk.

Many previous finishing works could improve some specific nature of silk, but it happened to deprave other important natures. The author's work is, however, specialized to improve the silk to be useful as wash and wear silk without harming its standard natures. So far, this work happened to be a overall innovative finishing method of silk textile.

VII. Part of management

His theses regarding with the silk industry management were composed of as followings.

(1) The sericulture producing mechanism in Korea
(2) The sericultural flow mechanism in Korea (1971)
(3) The analysis on low productivity of filatures in Korea(1968)
(4) The management analysis of filatures in Korea (1969)
(5) The historical review of silk exchange and the problems for silk exchange center(1971)
(6) The international trend and analysis of sericulture industry(1968)
(7) Statistical analysis for raw silk quality control (1975)
(8) The long run task force for silk exporting business (1976)
(9) The relationship of silk quality and silk reeling process (1976)

It would not be necessary to discuss the above written subjects again in this overall discussion, but one thing has to be emphasized is that the importance of better management is as much as importance of improving technics through out the industry concerned.

The modern business doctrines are composed of 4-M factors(Man, Money, Material, Management). Korean silk industry was evaluated as to be short of money and poor managment, so, there must be more

consideration to imporve the overall industry. In second, silk factory is exposed to have balance work on 3-Q system(Quantity per material, Quality, Quick production). Unfortuantely, the Korean silk factories are not in normal 3-Q system because of rather poor cocoon nature.

VIII. International activities

The author had visited to Egypt in 1969 and visited to Thailand in 1972 in order to help their sericultural technique by the sponsorship of UNDP. He had also visited to India in 1974 by the Indian government invitation and visited to Phylippines in 1976 by the sponsorship of IBRD to help their sericultural technical improvement.

These countries are located in tropical area and they are similar each other to be unique religious countries. Another word, Egypt is islam country, Thailand is budism country, India is hinduism and Philippines is catholic country.

The author had made his observation report after his return to Korea as followings.

(1) The development programme of sericulture industry in the U.A.R.(1969)

(2) The overall analysis on the Thai silk production mechanism(1973)

(3) The overall analysis on non-mulberry sericulture in the south east asian countries(1975)

(4) The overall investigation and evaluation for sericulture in the Philippines(1977)

The sericultural situation for these countries were similar each other at present. These countries, however, may achieve to be major sericultural productive countries soon or later.

The obtained observed conclusions for these countries are as followings.

1. Each country can produce silk for local use, but unfortunately the silk yarn produced in there does not provide the commodity value as of international transaction. technical promotion is required and the maximum effort is also required to supply silk for the customer abroad.

2. The method of material procurement has been stabilized which was more important than the promotion of technical problems.

The facilities improvement is also neccessary so that modern technical service may use with it. The financial investment is, however, delayed by the difficulty to securing adequate fund for the silk mills.

3. More technical improvement may be brought about in the future with continuous efforts and will have much success with international silk transactions in the future. The obtained specified evaluations are as followings.

a. The government did not support enough to have successful silk production or discontinued it after once started to promote in the past.

b. The finanical support has been under poor condition.

c. The administration machanism for silk industry is not in proper way.

d. The silk production mechanism is not also in proper way.

e. There is no law establishment to protect the sericulture.

f. There are small sericultural population who interest in the field.

g. There is no education facilities regard with sericulture in school so that may furnish continuously technicians in future.

h. The sericulture industry scheme is remained as poor condition.

i. The technical guidance seemed to be remained as only description and still not move on action.

j. The silkworm disease control has been under taken in carelessly.

k. The farmers willness to joint in sericulture service is not confirmed satisfactorily.

l. There is no concerned association to push the business in behind.

m. They are rich land resource for sericulture and be able to furnish better income than other crops.

n. They have also merit on cheap man power to develop the sericulture industry.

o. The climate condition is not proper for sericulture but the mountain site is useful for it and has merit to rear silkworm several times per year.

The author had felt strongly that there should have Eglish sericultural technique publication, so far, he had prepared two books of "Outline of silk processing" and "Sericultural technology" to help them out in technical aspect, They were distributed to all over the world and many sericultural people happened to know me very well by now.

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