# New Perspectives in Improving Cotton Fiber Quality and Processing Efficiency

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## ABSTRACT

*The recent rapid advances in spinning technology resulted in increasingly new demands concerning fiber properties. This paper is focused on ongoing research to meet current and future demands and identify factors and processes involved in quality improvement. The quality of fibers produced is determined by inherent factors and environmental influences. Improvement of fiber quality properties begins with improved varieties but genetic manipulation needs objective evaluation of these properties. Cotton breeders must be kept informed of the parameters required to meet the changes in cotton market and textile technology. Besides the major fiber properties, evaluation and improvement of more specific quality parameters could solve problems of spinnability and yarn quality. The main objectives of the current breeding programmes are the development of marginally longer and finer cottons, improvement of fiber maturity, strength and elongation, reduction of short fiber content and nepiness while improving uniformity of all fiber characteristics. Conventional and modern breeding methods and genetic engineering have been employed to reach these objectives. Future processing methods require more information on the distribution of single fiber properties to increase their efficiency. This can only be achieved by intensifying the development of single fiber testing methods. Furthermore, internationally harmonized calibration standards must be developed. The fiber properties that are relevant for processing, i.e. length, strength, short fiber content, maturity, fineness, neps, stickiness and non-lint content must be the basis for quality rating. Future processing methods need to integrate on-line measurement procedures increasingly, as part of the process optimization.*

## Part I. Improving Cotton Fiber Quality

### Introduction

The rapid advances in spinning technology in recent decades resulted in increasingly new demands concerning fiber properties. This work is focused on the ongoing research, to meet the current and future demands and identify factors and processes involved in quality improvement.

The adoption of new spinning methods, the advances in the traditional spinning process and the higher consumer demands call for extensive research and improvement of the raw material to keep pace with the current quality requirements of the spinning industry.

While it is relatively easy to manipulate and engineer the properties of synthetic fibers, the properties that nature imparts to cotton can be improved only through extensive research. Nevertheless improvement of the major fiber properties such as length, strength, maturity, fineness, has reached a threshold while the role of others i.e. elongation is not clearly defined yet. On the other hand the major fiber properties are not sufficient to describe the spinnability of any given cotton. In recent spinning techniques new properties have to be taken into account.

Identification of novel properties which have the potential to affect spinning process and effective use of these new parameters would be the route to the eventual goal which is to gain control over spinning procedure and to improve productivity and yarn quality. However the increasing availability of powerful units to assess fiber quality and the use of information technology offers a route by which the results of research can be interpreted to the user in the most accessible way.

Assessment techniques coupled with novel properties having the potential to control spinning process. The information obtained will enable the textile industry to use more effectively cotton properties in producing higher quality, lower cost products and in developing, new and improved consumer products from cotton.

### Fiber quality requirements

For any material to qualify as a textile fiber, it must possess certain essential properties. The primary requirements include: high length - to - width ratio, sufficient tenacity, flexibility and cohesiveness (Dever, 1995). In general cotton quality requirements of all spinning systems are summarized as following (Kechagia, 1994).

- Identifiable, measured fiber properties.
- Properly ginned cotton.
- Contamination free.
- Stickiness free.
- Even running lots.

However fiber properties are differently interpreted by the various spinning systems and the selection of the correct raw material for any of them, is of utmost importance to the spinner.

The major quality parameters for the traditional ring system, the open-end or rotor spinning and the recent innovations such as the friction (DREF) and the air-jet spinning are given in table 1 in descending order of importance. In table 2 are given the acceptable limits for the same parameters in ring and rotor spinning.

The use value of fibers depend mainly upon the above physical properties but as we mentioned these are not sufficient to describe the spinnability of any cotton. Others not included in this table are of equal or sometimes of greater importance. The estimation of short fiber content (SFC %) of neps and seed coat fragment as well as of colour, stickiness and foreign matter became necessity.

## Cotton fiber properties

An important consideration prior to any effort of improving quality, is to obtain reliable information on the properties, likely to be improved as well as the technical specification of the input for various end uses.

The molecular arrangement within the fiber and the conditions of fiber formation, impact the properties that make cotton fiber readily distinguished from all other textile fibers. All significant fiber properties are listed below, classified in relevant groups (Steadman, 1997; Hunter, 1998).

1. *Length Related Properties*: Staple Length Values; Span Length Values; Uniformity; Parameters for Length Distribution; Short Fiber Content.
2. *Transverse Dimensions of Cotton*: Micronaire; Fineness; Maturity.
3. *Tensile Properties*: Strength; Breaking Elongation.
4. *Non - Lint Content*: Average Trash; Trash Particle Size Distribution; Trash Type; Dust: Level and Size; Seed Coat Fragments; Foreign Matter and Contaminants; Neps.
5. *Cotton Colour*
6. *Miscellaneous Fiber Properties*: Fiber Friction; Cleanability; Microbial Attack; Cohesiveness; Compressibility and Resilience; Moisture Content.

Not all these properties are relevant for improvement and the word miscellaneous does not indicate they are non-significant to fiber processing.

An adequate knowledge of the measures of the above properties is of major importance for all segments of the textile industry. Intensive research has been recently witnessed on devising new instruments for measuring fiber properties and evaluating their significance to yarn processing.

The HVI (High Volume Instrument) system and the newly devised AFIS system, incorporated into the evaluation procedure, enable the objective measures of the most of the above listed properties on numerous samples. The high capacity systems allowed breeders to screen germplasm more efficiently (Xanthopoulos, 1998) and develop varieties of high fiber quality. In addition producers and ginners, receive more complete feed back for their product, while spinners can obtain consistent quality, through computerized blending procedures based on HVI and AFIS data.

## Factors influencing cotton quality

The secret of success in the improvement of final fiber quality lies in the good knowledge of internal fiber structure and of the external factors having an influence upon it. Variety, environment and the timing and type of cultural practices influence fiber formation and structure. These factors in addition to mechanical aspects of harvesting and ginning, affect secondary quality factors such as colour, hand and cleanliness.

Cotton variety accounts for over 80% of the variation in fiber length and strength while environmental factors account for 79% of colour variation and 59% of micronaire variation (Meredith, 1986). Trash is also influenced by environmental factors (Kechagia, 1998) although smooth or hairy leaf varieties differ in trash content. Elongation is correlated with both micronaire and strength, while length uniformity is influenced by ginning rather than by variety or environment (Dever, 1988). When attempting to improve any of fiber quality characters the influence of these factors must not be neglected.

Variety is the most important factor determining nearly all the quality and most of the agronomic parameters. Variety improvement must meet the spinners needs (Kechagia, 1994).

Environment ranks second in importance, conditioning the expression of the varietal potential in fiber parameters. Thus climatic conditions and cultural practices are critical.

Cotton reaches its highest quality at boll split, the only concern thereafter is to preserve the existing quality by applying less damaging practices. Extensive research proved that harvesting method mainly affect grade (Evcim and Oz, 1998; Brashears and Baker, 1998).

Ginning is the unavoidable but most hazardous procedure in fiber processing and the degree of damage depends on the harvesting method employed and the ginning method applied. Research to improve or preserve fiber quality has two options.

- Application of new technologies, (such as selective ginning and computerized ginning process).
- Breeding or selection of cotton varieties, less affected by ginning process.

Recent developments in harvesting and ginning practices have made significant advances in maintaining quality during these steps.

## Improvement of fiber properties

Nature favoured cotton with a unique structure and a high level of quality properties. Nevertheless endeavours are made to endow cotton fiber with improved properties. Improvement of fiber quality properties begins with improved varieties, however cotton breeders must keep informed of the parameters required to meet the rising changes in cotton market and textile technology. The properties dependent on the variety are fiber length and length uniformity, fineness, strength, elongation, neps and seed coat neps.

Fiber length and uniformity rank first in priority for ring spinning (Table 1). For many years, breeders efforts have concentrated on improving of fiber length. The length attained so far is adequate for normal uses, while extra long cottons are destined for specific products. Conversely, modern spinning machines are suited to the commercial lengths available.

Breeders should now endeavour to improve uniformity by decreasing short fiber content and increasing mean fiber length. The high short fiber content in bale cotton arises from damage at ginning and can be reduced by selecting varieties with low fiber to seed attachment force.

Improved fiber strength has been a priority objective for breeders since 1970 when rotor or open-end spinning was introduced commercially. Breeders have successfully developed new cultivars with an increase of 2-3g/tex in strength. However while the modern spinning processes (friction) increasingly require higher strength values, genetic variability for fiber strength is low among cultivated varieties.

Genes for extremely high strength were found in wild species and have been introgressed to Upland cotton by specific breeding techniques.

Improving fiber strength by conventional breeding or by using genes from wild species might be successful, but genetic engineering coupled with breeding provides new opportunities for direct improvement of fiber quality inherent properties (May *et al.*, 1998).

Modification of existing fiber properties and induction of novel properties requires identification of genes and genetic systems useful for cotton improvement (Stewart, 1991).

Monsanto is a leader in efforts to incorporate value added traits into cotton cultivars. Coding sequences are isolated from various species and inserted into cotton via Agrobacterium or particle bombardment mediated transformation. No commercial product is imminent from this research but breeding effort are progressing to isolate germplasm with stable expression of increased strength (May *et al.*, 1998).

Fiber elongation is an important property that has received little attention so far. The role of elongation has not been fully defined yet but there is evidence that it strongly influences processing efficiency (Kechagia, 1996). Recent research is focused on clarifying the effect of elongation on yarn quality and improving or inventing methods to assess fiber elongation accurately (Uster, 1998).

The new spinning technologies require mature cotton, with low micronaire values since more flexible and finer fibers are needed, but Upland cottons with low micronaire are relatively immature. An outmost priority objective for breeders, is therefore development of low micronaire varieties with fine mature fibers to meet the recent requirements. Estimation of micronaire value alone, in a breeding program, is not sufficient, fineness and maturity values must also be looked upon. Micronaire values are positively correlated with yield (rg=0.50) and this correlation makes it unlikely that breeders will try to develop low micronaire values.

Grade is mainly associated with harvesting and ginning practices. The Intelligin system from Zellweger Uster, not commercially available yet, measures moisture, colour and trash on line and uses the data to control drying temperature and to determine the number of seed and lint cotton cleaners (Ghorashi, 1998). General application of these systems would benefit all three constituents of cotton grade i.e. colour, foreign matter and preparation.

It is important to stress, that in the new spinning systems percentage of total impurities (neps, seed coat fragments, trash) has to be of minimum level. Most of them are variety depended but faulty ginning and immature cotton are important sources for their formation. Elimination of these features depends on combined efforts of breeders, producers and ginners. The AFIS device offered the opportunity of accurate estimation of impurities and facilitated the efforts of cotton breeders to develop cultivars with low forming potential. An equal effort is witnessed during production and ginning processes, which coupled with breeding would finally decrease them.

Cotton stickiness is an increasing problem, causing stoppages, frequent cleaning, impairment of yarn quality and lower productivity. Research on all aspects of stickiness is in progress, focused on methods for controlling insects or treatment of cotton in the field to prevent stickiness and on methods or instruments for assessing stickiness (Hequet, 1998; Mor, 1998). In addition, genetic engineering has been employed when the traditional methods failed. Incorporation of insecticidal genes or proteinase inhibitor genes in cultivated varieties are the two strategies tried to control the respective cotton pests.

Concern about environmental pollution stimulated interest in coloured cottons to avoid the use of chemical dyes and finishes. The possibility to using coloured cottons is very attractive, but again the breeders are called to solve the problems implied. Among the breeding objectives concerning coloured cottons are:

- Improvement of fiber quality which is inferior to that of white lint.
- Improvement of fastness of the existing colours and introduction of new ones.
- Development of coloured cotton fibers through genetic engineering. Transfer of genes for blue colour for denim is in progress.
- Preservation of purity of both coloured and white varieties to avoid upsetting seed production, variety maintenance and lint production processes.

## Summary

The main objectives of cotton fiber improvement are summarized in:

- Development of marginally longer and finer cottons.
- Improvement (where possible) of fiber maturity, strength and elongation.
- Reduction of short fiber content, neps and other impurities.
- Maintaining existing fiber quality.
- Improving evenness of all fiber characters.
- Improvement of fiber quality and colour range of coloured cottons.

Conventional and modern breeding methods as well as genetic engineering have been employed to reach these objectives. Research also focuses on improved process methods. Progress with cotton in Biotechnology, a new approach, is rapid and will probably be the first to reach commercialization.

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**Table 1. Fiber properties in different spinning systems.**

| Ring | Rotor | Friction | Air jet |
|---|---|---|---|
| Length | Strength | Strength | Fineness |
| Uniformity | Fineness | Fineness | Length |
| Strength | Length | Length | L. Uniformity |
| Fineness | L. Uniformity | L. Uniformity | Strength |
| Elongation | Cleanliness | Fiber friction | Cleanliness |

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**Table 2. Spinnable limits for efficient spinning.**

| Fiber Properties | Ring spinning | Rotor or open end spinning |
|---|---|---|
| Length | min 1-1 1/8 inch | min 7/8 inch |
| Uniformity | min 45% | min 45% |
| Micronaire | 3.5-5.0 | max 4. |
| Maturity | min 80% | min 70% |
| Strength | min 25g/tex | min 26g/tex |
| Foreign matter | max 2% | max 1.5% |

# Part II . Cotton Processing Efficiency

## Requirements on Raw Material Quality

Efficient automated production processes with high processing speeds which are prevalent in the textiles industry require an input of raw materials of high and well-defined quality which are monitored and homogeneous. Homogeneity for cotton, which is under review here, means that all areas of the feed sliver have identical fiber properties at all times.

Several steps are needed to ensure homogeneous feed material. First, the variety's homogeneity can be improved by breeding, growing and farming. In addition, defined and controlled blending of carefully chosen grades and bales is required for processing. Intensive mixing ensures that every sample of the feed sliver exhibits the same fiber properties.

Sophisticated measurement methods are needed to ensure defined and controlled blending. This presentation focuses on improvements in test equipment that are needed to meet future challenges of highly developed production processes.

Figure 1 shows different typical types of quality [Uster 1993]. The top chart shows cost-efficient quality. It is characterized by the fact that the material quality used is above the required minimum at all times.

Occasionally, however, the minimum values of the material quality can get near the required minimum line. The middle chart is a case of excess raw material quality. Here, both the level and the scattering of quality values are excellent by comparison to the required quality. The raw material costs, however, are threatening to become too high which will make production uneconomical. The lower chart shows an insufficient quality. Despite the high level of the quality used, a few extreme scatterings cause the unsatisfactory result.

Generally, causes for quality problems are:

- insufficient quality level
- large quality variation bandwidth
- quality outliers

Only constant monitoring of the feed raw material quality can ensure the cost-efficient quality which is desired.

## Aspects in Improving Cotton Testing

Important aspects in improving cotton testing which will now be discussed are:

- Harmonization
- Number of Test Procedures
- Quick Measurements of Every Bale
- Determination of Frequency Distributions / Single Fiber Measurements
- On-Line Measurements

### *Harmonization of Test Procedures and Results*

The harmonization of testing procedures may be broken down into three parts. First, the test procedure must be standardized and stipulated as a testing method. Only identical sample preparation and test implementation procedures will create a basis for similar results to be obtained in different laboratories.

A second step is the harmonization of testing equipment. This requires calibrating the equipment with cotton standards provided by a central body. Currently there are standards for strength, length and micronaire measurements. Other relevant properties such as stickiness, neps, short fiber content and maturity are tested but no standards have been provided. The consequent variation in results of different laboratories is considerable. Povidision of corresponding standards is clearly recommended.

Generally, test procedures would be preferred that do not need calibration standards of natural materials to avoid scattering and concomitant errors avoided.

Round tests are conducted in order to check the harmonization between the individual laboratories. Samples of one grade are sent out from one central body to all interested laboratories, and tested there. The results are then analyzed and compared. Every laboratory is notified of the extent of deviation of its results from the mean values of all results and can adapt or improve its testing procedure accordingly. The target of the round tests is to reduce inter-laboratory variation of results. Two institutes, which organize such round tests, are:

- Faserinstitut Bremen
- USDA AMS, Memphis, TN

In order to ensure that results from all laboratories remain comparable it is highly recommended that every laboratory participate in such round tests.

### *Number of Test Procedures for Each Property*

For many fiber properties there are different testing methods. Despite calibration, these methods lead to different test results for identical fiber samples. An example for this is the bundle tenacity results for one cotton variety which are listed in Table 1. Although the results of all testing methods are listed using the same unit (gf/tex), the results are clearly different. The strength measurement example likewise illustrates the international efforts to reduce differences due to differing test methods: Pressley values are to be avoided in the future, and HVI tests are to be calibrated with only one set of calibration standards (HVICCS exclusively).

**Table 1. Different Results for Bundle Tenacity of One Cotton Variety.**

| *Testing Method* | *Example* | *(Bremen Round Test)* |
|---|---|---|
| Pressley (0) | gf/tex | 44.67 |
| Pressley (1/8) | gf/tex | 26.36 |
| Stelometer | gf/tex | 21.08 |
| HVI (ICCS) | gf/tex | 22.17 |
| HVI (HVICCS) | gf/tex | 28.24 |

[FIBER 1993]

Future developments should result in only one testing procedure for one property.

### *Quick Measurements of Every Bale*

The development of increasingly rapid testing methods facilitate future testing of all important fiber properties for every individual bale with sufficient precision. These results and all other relevant information should then accompany the bale from the growing region to the processing mill or to the product, respectively, without any need for re-testing for trade or processing. In case of dispute, or where a re-test is required, an independent cotton testing facility should provide a "quick response" service.

If processing requires even more detailed results, further tests can be made at - or for - the mill before or during processing (e.g. on-line measurements).

### *Determination of Frequency Distributions / Single Fiber Measurements*

Currently only integral, characteristic values are noted for a number of measured fiber properties. With some kinds of testing equipment it is already possible to plot the complete graph of the distribution curve of the corresponding fiber property. These distribution graphs contain a host of information which cannot be inferred from the individual values, and which are of great significance for processing.

Fig. 2 shows the distribution graphs for the relative wall thickness of two different cotton varieties. The relative wall thickness constitutes the defined measurement for the degree of maturity of individual fibers. Despite identical mean relative wall thickness values a clear difference in distribution bandwidth can be seen, which is likely to lead to different processing properties.

Distribution graphs of individual properties may be obtained from groups of fibers. One example is the Almeter, which is used to determine fiber length distribution. With many properties only single fibers can be used to measure the distribution graph. A device to determine the properties of single fibers is the Advanced Fiber Information System (AFIS) of Zellweger Uster which can be used to obtain cotton fiber length distribution and fineness distribution.

Further development of the testing equipment will eventually permit the quick determination of more fiber properties using single fibers. Quality testing and consequently processing should make use of these opportunities.

## On-Line Measurements

Recently, the term on-line has been increasingly used. On-line measurement in the field textiles specifically means that measurements are taken during the continued production process. Measurements can include the raw material fed, process parameters, intermediate product properties and end product properties.

For raw material testing, on-line measurement means that the discontinuous raw material tests in the laboratory are complemented by a continuous monitoring of the raw materials introduced into the production process. Fig. 3 illustrates the shift of measurements into the production process.

- On-line measurements offer improved correlation between:
- Raw material characteristics / variations in characteristics
- Process parameters
- Product characteristics

The experience from these correlations can be used for choosing raw materials or for process control purposes. Finally the process parameters and the raw material feed can be controlled (open loop) or adapted automatically (closed loop) based on the readings of the on-line measurement.

In the ginning process there are systems even today which permit on-line measurement of fiber properties with a process control option. The Intelligin system from Zellweger Uster measures moisture, colour and trash content online and uses the data to control drying temperature and to determine the number of seed and lint cotton cleaners (Ghorashi 1998).

In the spinning process there are currently only a few systems for on-line measurement and process control. Examples for fiber properties which might be tested are nep content, trash content, stickiness, fineness and moisture content.

## Summary

The paper clearly shows that progress in cotton processing efficiency requires improvement of cotton testing procedures.

Important targets, which should be pursued for this reason when cotton testing is advanced, are:

- For all fiber properties that are relevant for production or products calibration standards need to be provided, as long as there are no testing methods which do not require calibration with standards.
- Every cotton laboratory should participate in the international offer of check tests in order to be able to compare its own results to those of other laboratories.
- The number of different measurement methods for individual fiber properties must be reduced in order to facilitate a clear comparison of results independent of the laboratory or testing equipment used.
- Methods for rapid testing of all significant fiber properties can be used to test the entire cotton raw material production for trade and processing.
- Single fiber testing methods should be further developed in order to be able to use not only individual characteristics but all of the information contained in property distributions.
- On-line measurement methods should be developed to enable more rapid process control.
- Furthermore it must be mentioned that highly developed cotton testing is an important basis for:
- Intelligent process control
- Reliable modeling and simulation of product properties (Expert Systems)

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**Figure 1. Different quality requirements.**

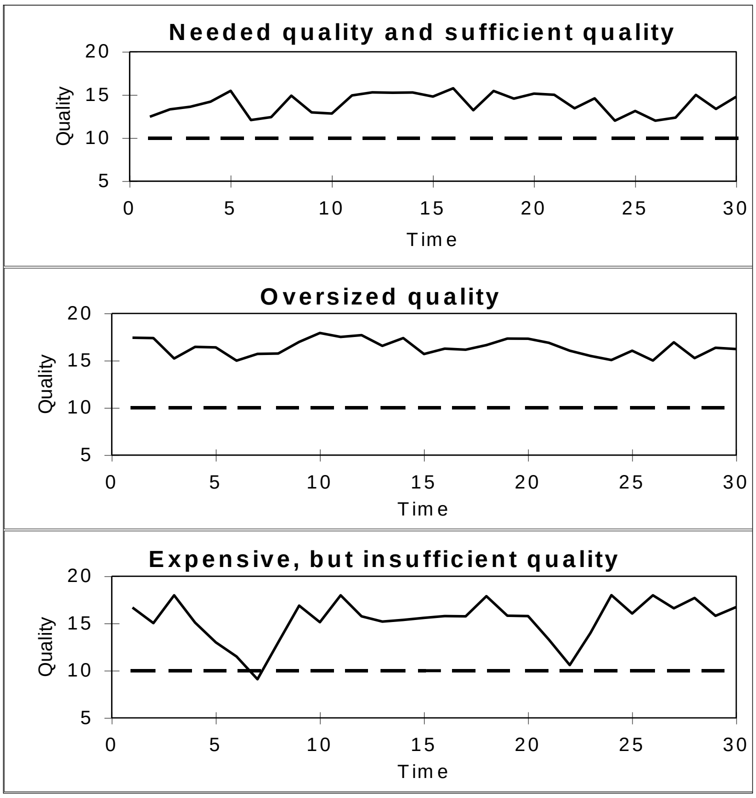
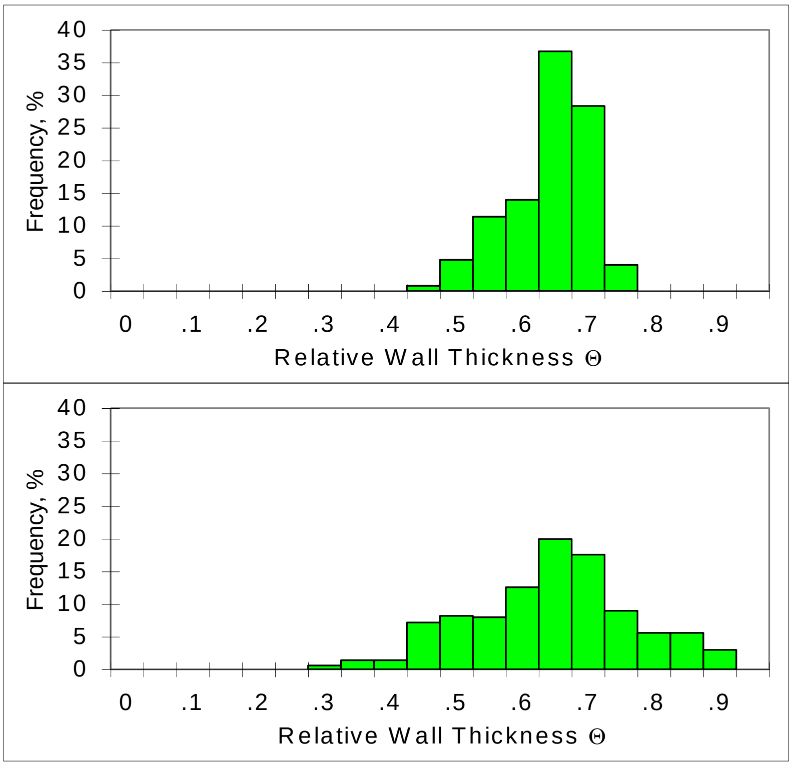


**Figure 2. Frequency distributions of the relative wall thickness of two different cotton varieties with the same average value.**




**Source: FIBER, 1996**

**Figure 3. On-Line measurement in the textiles processing process.**