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FURTHER EXPERIENCE WITH IMAGE-BASED LENGTH MEASUREMENTS, LI

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Abstract

IsoTester Li modules are currently calibrated to values established for USDA/AMS Long/Strong and Short/Weak HVI calibration cottons. HVI-based values are used for Long Fiber Content, UHM (and thus Staple) and LUI (and thus ML). AFIS values are used for Short Fiber Content, indirectly. Performance results for production IsoTester Li modules so calibrated are reported. SFC measurements are maturing to the point of commercial usage, along with well-established LFC measurements.

Introduction and Background

In this 2003 Cotton Beltwide Technical Conference on Fiber Quality Measurements, Schaffner Technologies reported another new method of making fiber length measurements (Yupeng, et al., 2003). The method uses a new form of tapered beard, automatically prepared two beards at a time, and digital color image processing technologies to determine length properties of these beards. We refer to the method and apparatus as length by images, Li.

We gratefully acknowledge support for early development of the Li method by Cotton Incorporated and by USDA's Southern Regional Research Center (Xiaoliang and Thibodeaux, 2003). We also thank USDA/AMS/Memphis for provision of all the cotton standards for which IsoTester Li + C +T data are reported here. Productive and challenging brainstorming sessions deserve special personal thanks to Michael Watson, Devron Thibodeaux , Xiaoliang Cui and Jimmy Knowlton. The joint work on Li was and is part of SRRC's, CI's and AMS's efforts to investigate the implications of short fiber content SFC to breeding, marketing and processing, to refine SFC measurements, and to examine enhanced export opportunities for US cotton.

Evaluations of the Li engineering prototype in 2002 and several production Li modules in 2003 (US, Brazil) exceeded our expectations for "True" SFC, which was the initial focus. (See below for definition of "true.") Fortunately, Li provided very good long fiber content LFC data as well. That is, the precisions and accuracies of conventional UHM and LUI data products were comparable or superior to existing instruments.

In more basic fiber measurement science terms, it could be reasonably contemplated in late 2002 that Li indeed had good potential to become a new, less-biased, more absolute reference method. This potential existed because of the ability to provide useful length probability density functions, PDFs (or synonymously, complete length distributions or histograms). Fundamentally, any and all length statistics, such as 2.5% Span Length, UHM, Mean Length, LUI, Lower Half Mean = LHM [9,10] or SFC, by number or by weight, can be directly determined from rigorously-calibrated PDFs. We call such determinations "true" data products. Further, such absolute and fundamental determinations could be made without use of calibration cottons, in the limit. Development of Li into such a basic and absolute reference method of providing rigorous PDFs can be appreciated as another high and challenging goal.

The results reported at BW 2003 were obtained using a mix of traditional amount versus length analyses and PDF analyses. Briefly summarized: UHM determined using Li PDFs did not agree well with current HVI data products. We do not have a good explanation for the differences between two totally independent methods; there may not be one. A traditional beard amount Ai versus x, followed by a traditional calibration, did agree, quite well. However, LUI and especially SFC could be well determined from the raw, or uncalibrated, PDFs. We thus faced a major decision in early 2003.

At the risk of over-simplification, but in the interest of brevity, we could either

1. attempt to rigorously calibrate the basic PDF approach; and then produce true data products, following basic fiber science principles; or
2. use a mix of traditional and raw PDF analyses to produce raw UHM, LUI and SFC data products; and then use standard cottons with rigorously established values to produce calibrated data products.

Development Path 1 would move the Li method toward fulfillment of its potential as an improved reference method for true length data products. Path 2 would more assuredly produce data products that would be familiar to commercial trade in accuracy (or level) and precision (or reproducibility). Resources and time were not available in 2002 - 2003 to follow both the "true" and "calibrated" data product design paths for Li.

Because of world-wide, commercial use of and familiarities with HVI data products, we pragmatically chose to emphasize development Path 2. More technically, we chose to use USDA/AMS Long/Strong and Short/Weak HVI calibration cotton standards because of the rigorous quality control procedures with which USDA/AMS prepares these cotton standards and establishes precise and accurate data product length and strength values for them. Availability of strength values on these cotton standards provides another justification for their use. In a highly related, parallel effort to Li, to be reported in due course, STI is also developing a next generation strength measurement, including a newly-designed Ultra Rapid Conditioning module (IsoTester, 2001). Indeed, testing tapered beards for both L and Str was the fundamental reason we chose to develop a new form of tapered beard.

[The following remarks are offered by the senior author for elucidation. The principal Inventors of the Li method are Kyle Shofner and Yupeng Zhang. The initial experience with the Li engineering prototype in 2002 revealed that PDFs provided by the Li method were basically correct and potentially quite useful. Comparisons by STI between AFIS and IsoTester PDFs indeed revealed general similarity. Some noteworthy differences could be explained (starting point offsets or baseline distances, fiber fragment exclusions, long fiber breakage, response function problems, etc). These comparisons, and other experiences, support the conclusion that the Li method has the potential to become a new, absolute reference method for fiber length, particularly if the PDFs can be rigorously calibrated. This is the high goal mentioned above.

These favorable experiences for the new Li method are at least gratifying to the senior author, the principal inventor of the AFIS method. Both inventions had among their objectives provision of basic and rigorous PDFs from which LFC and SFC data products could be derived. It can be restated that one of the original objectives for the Li method, in our second visit to the basic length measurement problem, was provision, ultimately, of improved, rigorously calibrated PDFs. We and others shall undoubtedly revert to this important subject in due course, in future publications.]

This audience and certainly these authors will find most interesting and encouraging Dr. Eric Hequet's paper in this Conference on thorough and basic investigations into rigorously calibrating the IsoTester's PDFs (Hequet, 2004). These investigations further confirm the potential of the Li method to become a new, very basic, absolute reference method. International Textile Center, Lubbock, Texas, where Dr. Hequet is Associate Director, has a fully automatic Li instrument in the 2003 IsoTester version.

Building on the genuinely exciting Li engineering prototype experiences in the late Summer and Fall of 2002, and also with 2 field prototypes, STI designed and manufactured in 2003 several (~ 14) semi-automatic (US, Brazil, Paraguay) and fully automatic (US) Li modules. The semi-automatic Li/2 modules were for RapidTesters and the fully automatic Li modules were for IsoTesters.

Figure 1 shows a 2003 IsoTester having Li + Color + Trash + Moisture Content measurement modules. This IsoTester configuration is a fully automatic version, typical for gin-located instruments, along with STI's Gin Wizard™. This version is also typical for the lab-located versions, except that MC is usually not included. Automatic Strength (plus URC where needed) and Micronaire modules may be retrofitted to this version IsoTester (and to some RapidTesters).

We now limit the discussion to LFC and SFC data products from the Li apparatus and method, when calibrated with HVI LS and SW cotton standards.

Li Data Products and Calibrations Based on HVI Calibration Cottons

Overview

Whereas USDA/AMS establishes long fiber content LFC values of UHM and LUI on its HVI LS & SW calibration cottons, it does not currently provide established values for SFC. However, provisions of rigorous values for SFC are under active consideration. One approach, introduced by USDA/AMS, is to predict SFC based on LFC data products already provided by HVI. The method is referred to herein as the "Knowlton Method or Equation" in recognition of the AMS Engineer who led its development and refinement (F. Shofner et al., 2004). Its data product is designated herein as SFCp. Further experience with this predictive method, using LiUHM and LiLUI directly from the IsoTester Li module to predict LiSFCp, reveals that it is remarkably precise.

Importantly, the reference method used for these predicted data is in fact AFIS, because Knowlton's power law regression formulation is based on AFIS SFC data for reference. AFIS is currently the primary reference method for SFC and, notably, its SFC data products (by number or weight) are "true" or derived from PDFn or PDFw.

Since the IsoTester Li method also provides LiUHM and LiLUI, two fundamentally different SFC data products can be provided and compared to SFCp: the measured LiSFC (calibrated;from raw PDFs) and the predicted LiSFCp (directly calculated; from LiUHM and LiLUI). The SFCp data are themselves calculated from the UHM and LUI values provided on the standards boxes by AMS. Thus these SFCp values are indirectly AFIS readings.

Results

Figure 2 shows the IsoTester interface screen for Li + C + T + MC data products. This section is limited to Li results, seen in the rightmost 5 columns. Since Staple = 32 UHM and ML = UHM x LUI, by definitions, we need only present and discuss results on LiUHM, LiLUI, and LiSFC. It is repeated, for clarity, that the indicated LiSFC is the calibrated value determined from measurement of raw PDFs. Independently determined LiSFCp results (from LiUHM and LiLUI) will be given below for comparisons. (Presentation of LiSFCp as an optional data product column is under consideration.)

The operator-selectable graphs inset onto the interface screen are raw fiber amount (Hertel's "amount") versus distance x, Ai(x), and PDFs for the 2 simultaneously-acquired beards, one red and the other blue. Figure 3 is an enlargement of the beard images. It may be appreciated that these images are themselves data products. Figures 4 and 5 are enlargements of the raw PDF and Ai graphs, which enlargement is easily implemented by the operator for careful inspections during testing. PDFs may be routinely presented to the operator and archived in the IsoTesters' database, along with the amount versus length, Ai, data products and compressed beard images.

Figures 6 and 7 show IsoTester LiUHM and LiLUi determinations (ordinates) versus AMS HVI determinations of UHM and LUI (abscissas). The red triangle entries are the post calibration values for LS and SW. Such post calibration, retest values for the calibration materials should be and are very nearly on the 1:1 line since this procedure is a 2 point calibration. The 8 other points (blue diamonds) are for USDA/AMS Staple Standards 29 through 38. These cottons were also provided by USDA/AMS. For these graphs, 8 IsoTester replications were averaged for each triangle or diamond point. Average CVs will be presented later in this Section.

The high correlation and general agreement for the staple standards are most encouraging. They are necessary proof that the completely independent (because of independent measurement principles) Li and HVI methods calibrate equally well to cotton standards. There are some small but noteworthy differences from 1:1 agreement for the staple standards. All that can be hypothesized now is that the HVI and/or procedures used for LS and SW standards may have been different than the HVI and/or procedures used for the staple standards. The IsoTester used was of course the same.

Figure 8 shows LiSFC and Figure 9 shows LiSFCp, both verus SFCp. The SFCp data were calculated by applying Knowlton's equation to the AMS-provided values of UHM and LUI for HVI LS & SW and for the Staple Standards. The AMS values placed on the well-blended cotton standards boxes are the result of numerous test replications. As explained above, this prediction equation used AFIS data for reference, so this axis is indirectly an AFIS SFC axis. SFCp are used in both Figures 8 and 9 as the independent variable (abscissas) for simplicity and consistency of presentation here. We note that earlier comparisons were directly with AFIS (F. Shofner et al., 2004). Also, SFCp values were determined for the HVI LS and SW calibration cottons and used for the calibration values for the independently-determined LiSFC.

Inspection of Figure 8 again reveals that the triangular data point entries are from the LS and SW HVI calibration cottons and are seen to lie very near the 1:1 line. The high correlation R^2 between the LiSFC, determined by raw PDF measurement followed by conventional calibration, and the SFCp, a prediction based on AMS-determined values, is very encouraging.

Figure 9 shows LiSFCp versus SFCp. Both abscissa and ordinate values are predictions based on application of the Knowlton formula. Neither are "calibrated" but rather both are calculated using either IsoTester LiUHM and LiLUI (ordinate) or HVI UHM and LUI (abscissa) in the same formula, a formula optimized for HVI, not IsoTester. The very good agreement follows from the very good agreements on UHM and LUI

The general agreements and high correlations seen in Figures 8 and 9 are also indeed encouraging. They support the position that SFC measurements are maturing in accuracy to the point of confident commercial use. What about precision?

All of the plotted points in Figures 6 - 9 are the averages of n = 8 reps for the IsoTester tests. The generally similar system responses indicate that the IsoTester Li, HVI or AFIS report similar data, with high degrees of correlation. The average CVs for the various n = 8 replication IsoTester Li measurements are listed in Table 1. Generalizing, our experiences typically reveal average CVs ~ 1% for LiUHM, ~ 0.5% for LiLUI and ~ 6% for LiSFC. These reproducibilities are typical for IsoTester Li and comparable or superior to existing HVI and AFIS. Average CV ~ 4% results for LiSFCp, the data product predicted from LiUHM and LiLUI, using Knowlton's formula, are also typical for the IsoTester and also for HVI.

Thus, in the opinions of these authors, the accuracy and precision of SFC readings are approaching the point of confident commercial utilization, globally. Work in several laboratories is actively under way to consolidate and refine the several good approaches to SFC measurement now under consideration and thus to accelerate their wide-spread use.

Summary and Conclusions

The primary thrust of this progress report has been to concisely prove that the modern, image-based length by images method Li exhibits essentially identical responses as current generation instruments, when conventionally calibrated and when producing conventional, commercially known data products. A secondary thrust has been to elucidate the advantages of image-based measurement modules and, thus, to justify them. The merits include new means of calibrations and new data products. We also explain how orderly transitions to these improvements have been anticipated.

These results on image-based length have collateral efforts on image-based color and trash (F. Shofner et al., 2004). Following conventional calibration procedures, IsoTester Length, Color and Trash data are provided for conventional data products currently and widely used in cotton commerce:

Data Products		Calibration Materials
Length:	UHM, LUI, SFC	HVI LS and SW Calibration Cottons, 2
Color:	Rd, +b	Ceramic Tiles, 5
Trash:	Count, %A.	Large Pictures Under Glass, 6

The Li results reported herein are compared to current generation HVI or, indirectly, to AFIS (for SFC), to demonstrate that the new image-based methods respond essentially identically. These ~ 1:1 responses between new and existing methods, which are based on very different physical principles, are major accomplishments, representing major efforts. These ~ 1:1 responses mean that the so-calibrated methods have identical accuracies. Said accuracies are completely dependent upon the accuracies of the methods by which the cotton standard values are established.

Precisions are equivalent or superior but, more importantly, the new image-based methods, with their inherently high spectral and spatial resolutions, enable opportunities for new methods of calibration and new data products. Thus, for only 2 examples: the image-based Li method enables a new absolute reference method based on rigorously-calibrated PDFs; Li also enables use of color images of tapered beards for inspection.

Since SFC is currently a "hot topic," the authors offer the opinion that SFC readings are rapidly approaching the point of confident commercial utilization, globally, like LFC readings. Work in several laboratories is actively under way to consolidate and refine the several good approaches now under consideration and thus to accelerate their wide-spread use.

From the outset of these developments, it has been one of STI's basic objectives to provide for orderly (ie, transparent and seamless) transitions to improved and/or more relevant data products, whenever market forces demand them. These goals can be better appreciated, now that image-based technologies are in hand. Thus we respectfully submit that the technical objectives have indeed already been met for image-based length (and color and trash (F. Shofner et al., 2004). We also report, thankfully, that the market is responding favorably.

We are pleased to be able to now report that some leading ginners are using IsoTester & Gin Wizard instruments to test mini-ginned fiber from incoming seed cotton (C. Shofner et al., 2004). These innovative procedures, most of which were in confidential and early development status until this past ginning season, indeed enable better optimizations of the entire cotton utilization processes, including marketing. Further, they also enable ginning companies to reinvent themselves and buy seed cotton and optimally gin and merchandize it, rather than ginning for a fee. Ginning in this way is not practiced in the US but is common in other parts of the world.

Still further, the nearer to the ginning or initial warehousing point, and the sooner and more completely fiber quality data are available, the better for feedback and feedforward measurement and control optimizations of the overall process. These gin- and warehouse-located fiber quality measurements and procedures, most of which are strongly facilitated by the Internet, have enormous potential.

Our pragmatic choice of HVI calibration materials and methods to calibrate IsoTester Li modules should not be interpreted as stating that existing methods and apparatus are regarded as better. One should never conclude that equivalences (or differences) in readings of "new" versus "old" technologies imply fundamental superiority of one or the other of totally different methods; one can only conclude that they respond the same (or differently) to the same cottons. Other considerations have to be made, objectively and thoroughly, to conclude that one or the other method is better. We respectfully submit that Li offers significant advantages for long term commercial use.

References and Notes

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Xiaoliang Cui and D.P. Thibodeaux, "Update on the SFC Research at SRRC," Fiber Quality Measurements Conference, Beltwide Cotton Conferences 2003 Proceedings, Nashville, Tennessee.

Xiaoliang Cui and D.P. Thibodeaux, "Statistical Parameters of Cotton Short Fibers", Fiber Quality Measurements Conference, Beltwide Cotton Conferences 2004 Proceedings, San Antonio, Texas.

The IsoTester is being expanded to provide all 5 current HVI data products, Li + Str + C + T + Mic, all of which modules have been manufactured by STI, as early as 2001. Also see schaffnertech.com.

Eric Hequet, "Preliminary Evaluation of an Image-based Length Measurement," Proceedings, Beltwide Cotton Conference 2004, San Antonio, Texas.

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