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SMALL TRASH IDENTIFICATION IN COTTON

Jonn Foulk and David McAlister
USDA-ARS Cotton Quality Research Station
Clemson, SC
David Himmelsbach
USDA-ARS Quality Assessment Research Unit
Athens, GA
Ed Hughs
USDA-ARS Southwestern Cotton Ginning Research Laboratory
Mesilla Park, NM

Abstract

Cotton always has a certain level of trash associated with its fibers and this trash is known to affect processing efficiency. The elimination of trash, removal of certain trash types, or trash sizes has often been a means to improve processing efficiency. The goal is to determine the total degree of fiber contamination and understand how each fraction impacts textile processing. This research will determine if new Trashmeter software developed for the HVI can evaluate trash and its particle size distribution. Coupled with this trash identification software is the use of mid-infrared spectroscopy that compares trash particles or dust to a spectral database of authentic samples to better determine problematic trash types. The HVI Trashmeter has emerged as a robust image analysis program able to successfully locate, count, and size trash particles in cotton. Mid-infrared spectroscopy appears to be able to predict trash type and demonstrates that the rotor dust accumulating in open-end spinning appears to be hull and shale rather than seed coat fragments.

Introduction

Cotton remains one of the most important natural fibers. The cotton textile business has become increasingly competitive with the US maintaining its edge by competing in the world market. Textile processing is influenced by trash components found in all cotton bales, which are inhomogeneous and contaminated with troublesome trash. Cottons and their trash components are diverse in nature and respond differently to textile cleaning and further processing. The nature of trash is what determines the efficiency for further textile processing. Since cotton is produced in the field rather than at a manufacturing facility, it remains complicated to control all trash generated in production. It is well understood that seed coat fragments and motes represent a small fraction of trash and are extremely difficult to remove from within the fibers while other trash, such as leaf, is relatively easy to remove. This trash removal is due to fiber cohesion and can be related to the length, strength, crimp, fineness, and trash type. Long and strong fibers may offer additional length for entanglement while finer fibers may be easier to clean. The type and amount of trash, fiber-to-trash adhesion, and how well its behavior mimics a fiber determines the ease of trash removal. Standardized testing was developed for cotton trash measurement because trash affects further processing and utilization.

Historically, cotton fiber measurements were first performed by humans specially trained to differentiate fibers based on their length, strength, fineness, color, and trash (Shofner and Shofner, 2000). The United States Department of Agriculture (USDA) Agricultural Marketing Service (AMS) classes and grades cotton for a small fee (Agricultural Marketing Service, 1993). These cotton fiber measurements have progressed from a subjective human classer to the objective High Volume Instrument (HVI). A representative cotton sample tested on a properly maintained instrument and performed under similar conditions results in values that are impartial and non-biased. The USDA categorizes various agricultural products with cotton trash measurement (percentage of surface area) of non-lint materials obtained using a scanning video camera mounted within the HVI. This percentage of non-lint surface area is correlated to the classer's leaf grade (1 through 7 and a 'below grade'), which is a visual estimate of cotton plant leaf particles in cotton.

Certain aspects of trash affect processing because they have different buoyancies, diverse binding forces between fibers, and degrees of fiber entanglement that affect trash removal. Trash samples absorb and maintain their moisture contents differently than cotton fibers. Cohesion can be enhanced between cotton fibers and trash with increasing levels of moisture content in trash. Different varieties of cotton will vary with changes in the nature of trash due to diverse genetic, growing, harvesting, and ginning conditions. Genetic differences as to how well the seeds are held by fibers will impact trash levels while the proportion of leafy matter, stem, particles, soil, and dust depend on harvesting or ginning techniques. If the types of trash are different, the cleaning behavior varies considerably so the cotton and its trash component must be evaluated.

The classification of cotton trash into various categories based on type of trash or particle size may provide additional information regarding the ease of trash removal, problematic trash type, and optimal trash size for textile process removal. Cotton contains troublesome trash with conflicting issues such as leaf vs. seed coat, size vs. type, and size vs. distribution. These conflicting issues are confounded because trash particles can be difficult to locate, measure, and describe since trash can arise from many components and can be irregularly sized, erratically positioned, partly covered by cotton fibers, or light colored in nature. These trash particles originate either from the cotton plant with various parts of the leaf, stem, bark, seed, and hull or from the local environment including grass, sand, dust and other contamination. Cotton contamination including large trash and small pepper trash is commonly referred to as visible foreign matter. Individuals commonly refer to pepper trash as having a size around 0.02 in, while seed coat fragment typically range from 0.017 - 0.025 in. Respirable dust is commonly referred to fall between 0-15 μ (0-0.0006 in), micro-dust 15-50 μ (0-0.002 in), dust <500 μ (<0.02 in), and trash >500 μ (>0.02 in) (Ghorashi, 2000).

Ginners often increase the level of cleaning to extract more trash and improve the cotton grade. Consequently, during these additional cleaning steps trash particles decrease in size (Baker et al., 1992). Cleaning cotton causes fiber loss and fiber damage so a ginner must set the operating speed, drying characteristics, pre-cleaning, and lint cleaners in obtaining ginned cotton. This reduction in particle size has often been thought to represent a detrimental influence on the spinning process and finished goods. With regard to fiber properties and trash contamination, ginning impacts trash with roller ginned cotton typically demonstrating higher residual trash content and longer fiber lengths than saw ginned cotton (Verschraege, 1989).

Open-end spinning is more sensitive to trash content than ring spinning and the desired spinning system to evaluate the impact of trash (Baker et al., 1994). The opening roller in open-end spinning is very efficient at cleaning cotton due to the large number of wire points passing over a small amount of cotton with centrifugal forces effectively ejecting small fragments (Verschraege, 1989). While this mechanism is effective at removing a significant portion of the trash, further fragmentation of the trash particles does occur. Cottons with larger particles are considered easier to clean than cotton containing many small particles that lack particle mass for optimal centrifugal force extraction. Low efficiency rates during open-end spinning are often the result of various types and sizes of trash particles including dust and micro-dust becoming trapped in the rotor and forming a complete ring of trash in the rotor groove. Progressive accumulation of impurities within this groove interferes with yarn formation (Vaughn and Rhodes, 1977) and gradual deterioration of the yarn producing neps, thick places in the yarn, or ends down. Textile mills require cotton quality be maintained for optimal efficiency with minimal yards of second quality finished goods.

The HVI provides a rapid trash measurement at a low cost using a video camera at one set of conditions. Recent HVI software developments are able to rapidly quantify cotton trash and provide a particle frequency distribution (Ghorashi, 2000). As processing speeds increase, continued improvements in measuring cotton are desirable. New techniques or instruments may be necessary to provide rapid, consistent, quantitative, and additional fiber property results with confirmed reliability. Work has progressed with infrared microscopy able to confirm the utility of infrared mapping of cotton biological components (Himmelsbach, 2000). The goal is to determine the total degree of fiber contamination and understand how each fraction impacts textile processing.

Materials and Methods

Trash Tiles

Cotton Trash Tiles were created using a compilation of cotton trash particles removed from cotton and sieved through a series of stainless steel USA Standard Testing Sieves (2 in deep, 8 in diameter). These sieves contained wire mesh with a size of 10, 18, 35, and 60 and respective mesh openings of 0.0787 in (2.0 mm), 0.0394 in (1.0 mm), 0.0197 in (0.5 mm), and 0.0098 in (0.25 mm). The smallest cotton trash particles that passed through all mesh openings were collected in a collection pan in series. To create a Cotton Trash Tile, multiple single trash particles from each collection sieve were physically placed and uniformly positioned on C-line clear contact paper and affixed to acid-free HammerMill pastel cream 67 lb cover stock.

USDA AMS prepares HVI check samples of Trash Under Glass to simulate trash particles mixed with cotton fibers. Six HVI Trash Under Glass samples (USDA AMS, Standardization Staff, Memphis, TN) were evaluated with particle counts from 8 to 52 and a percent area ranging from 0.15 to 1.81 %. Trash under glass samples 1, 2, 3, 4, 5, and 6 had USDA AMS percent areas of 0.15, 0.26, 0.62, 0.80, 1.00, and 1.81 % with respective particle counts of 8, 15, 23, 37, 33, and 52.

Experimental Tiles were created by inserting, sizing, and positioning circular and square particles on paper. These solid particles were constructed using the computer drawing program TurboCAD Professional version 7. Tile sets were printed on acid-free HammerMill pastel cream 67 lb cover stock using a Hewlett Packard LaserJet 1100A at 600 dpi. Particle size diameter or side length ranged from 0.009 to 0.16 in. Each individual experimental tile consisted of particles uniform in size and distribution. Tile set 1 consisted of circular particles (0.01, 0.02, 0.04, 0.08, 0.16 in diameter), tile set 2 consisted of square particles (0.01, 0.02, 0.04, 0.08, 0.16 in side length), and tile set 3 consisted of circular particles (0.002, 0.003, 0.004, 0.005, 0.006, 0.007, 0.008, 0.009 in diameter).

Tile Analysis

After printing, Experimental Tiles were scanned at 600 dpi using a HP OfficeJet G85 scanner. These scanned images were imported and analyzed using UTHSCSA ImageTool version 3 (free image processing and analysis program developed at the University of Texas Health Science Center at San Antonio, Texas and available from the Internet by anonymous FTP from maxrad6.uthscsa.edu). This software counts particles and then provides the area, perimeter and diameter for each circular or square particle.

The new Trashmeter software package was utilized on the Experimental Tiles, HVI check samples of Trash Under Glass, and the Cotton Trash Tiles. The Experimental Tiles were placed on the HVI observation window, evaluated, and repositioned 10 times. HVI check samples of Trash Under Glass and Cotton Trash Tiles were placed on the HVI observation window, evaluated, and repositioned 6 times. To evaluate the new and improved HVI Trashmeter, cotton quality trash measurements were performed on a HVI 900A (Zellweger Uster, Knoxville, TN) by the Testing Laboratory at Cotton Quality Research Station (CQRS). The viewing area of the HVI is 9 in^2. The HVI Trashmeter camera has a sensing array of 510 by 480 pixels with a resolution of 484 by 464 pixels with every other line used. The Trashmeter ignores trash particles less than 2 pixels in area for noise reduction with the software calculating the total trash, percent of viewed area, and trash particle distribution. The smallest viewable trash accepted by this software is 0.013 inch. The Trashmeter allows cotton to be evaluated for the number of trash particles per various classes of trash size, distribution of trash particles, average particle size, and sum of trash particles.

The diameters or side lengths of all particles in all experimental tile sets were achieved by visual measurements (subjective measurement) on a Zeiss Stemi SR stereomicroscope at 50X magnification.

Cotton Ginning

Sample bales of cotton that had been spindle picker harvested were selected because of their wide range of trash levels. Some bales are representative of a typical harvest at any one location while others were spiked with 30 pounds of mostly whole hulls at the gin stand just prior to ginning to represent potential harvests. Bales were all harvested, ginned, and baled by commercial methods.

The first lot of cotton bales consisted of 12 lots of pima cotton with 3 replications and 4 different treatments with treatments 3 and 4 spiked with hulls. These bales of cotton contained various levels of trash and dust. Ginning treatment 1 consisted of one cylinder cleaner, roller-gin stand, and zero lint cleaning. Ginning treatment 2 consisted of cylinder cleaner-stick machine-cylinder cleaner, roller-gin stand, and Aldrich beater-super jet lint cleaner. Ginning treatment 3 consisted of one cylinder cleaner, saw-gin stand, and zero lint cleaning. Ginning treatment 4 consisted of cylinder cleaner-stick machine-cylinder cleaner, saw gin stand, and one saw-type lint cleaner.

The second lot of cotton bales consisted of 12 lots of upland cotton with 3 replications of a standard and small seed variety. These bales of cotton contained various levels of trash and dust. Typical ginning equipment was used to gin the cotton with all lots passed through two 6-cylinders and one stick machine for seed cotton cleaning. Half of the lots were ginned on an experimental saw gin stand designed to minimize seed loss and the other half were processed through a standard saw gin stand. All lots were processed through one saw-type lint cleaner

The fiber properties (see Table 1 for official classification) for all ginned cotton were determined by High Volume Instrumentation (HVI). The HVI allows cotton fibers to be tested for length, strength, fineness, color and trash according to established standards (ASTM, 1993).

Textile Processing

Cotton was processed through the same modern Truetzschler Opening and Cleaning line and card to produce a 60 grain sliver at 100 lbs/hour. All cotton was processed through the following sequence: blending hoppers in a Fiber Controls Synchromatic Blending System, Axi-Flo cleaner, GBRA blending hopper, a RN cleaner, RST cleaner, DUSTEX fine dust remover, chute fed DK803 card, Rieter RSB draw frame, and SE-11 open-end spinning. A half pound sample was collected from the card mat and card sliver for Advanced Fiber Information System (AFIS) testing. The beginning weight, waste at each cleaning point, and sliver weight was recorded at each point. All collected waste was Shirley analyzed. An evenness and AFIS test were performed on the card sliver. Through the first stage of drawing, 55 grain sliver with 6 ends up were produced and an evenness test performed. Pima sliver was run on open-end spinning frame into 20/1's yarn at 80,000 rotor speed with a 3.75 TM and a comber roll of 8,000 using a T40 mm rotor. Upland cotton was spun at 100,000 rotor speed under the same conditions. In spinning, the waste was saved, rotor dust collected, and ends down recorded.

The data were statistically analyzed with the General Linear Model procedure in SAS using Duncan's New Multiple Range Test ($P<0.05$) to detect differences between means (SAS Institute Inc., 1985). The exploratory Stepwise procedure in SAS was used to determine significant variables and the General Linear Model procedure in SAS was used to determine an equation.

Spectroscopy
Raw dust was collected from the rotor groove, analyzed by mid-infrared spectroscopy, and compared to a database of spectra of authentic samples. Fourier-transform infrared (FT-IR) spectra in the database and of dust samples were collected using Nicolet Magna 850 FT-IR bench (Thermo Nicolet, Madison, WI) employing a DuraScope (SensIR Technologies, Danbury, CT) single-contact ATR sampling device equipped with diamond crystal and video imaging. The IR spectrometer was equipped with a globar source, KBr beamsplitter, and deuterated triglycine sulfate (DTGS) detector. Spectra of dust samples, collected from each of the twelve lots, were obtained from three separate dust sample readings. Analysis of the complex trash mixture proceeds to match trash within its database, and determines problematic trash type.

Results and Discussion

Counting and sizing cotton trash by hand would be a very tedious, time-consuming, and subjective process. Small amounts of cotton trash were sieved for size separation to verify initial measurement applicability of this software. Software written by Zellweger Uster for use on their 900A HVI appears to be a robust image analysis system able to rapidly locate, count, and size trash particles of various colors, shapes, and sizes. Evaluation of Cotton Trash Tiles appears to show the HVI Trashmeter does well at locating and measuring the mean size and distribution of cotton trash particles placed on contact paper and affixed to paper cover stock (Figure 1). The mean size for trash that was collected from various USA Standard Testing Sieves presents a linear relationship ranging from 122.5 pixels (sieve size 10) to 6.4 (trash that passed through the smallest sieve size of 60). This preliminary test with uniformly located trash shows that asymmetrical trash diverse in origin and color can be easily measured with the new Trashmeter software.

Trashmeter software assessment requires one to understand how it differentiates trash located within cotton samples using Trash Under Glass check samples. Trash count, mean pixel size, total pixel area, and trash classification for samples can be seen in Table 2. Results indicate that with new software the HVI 900A Trashmeter is able to estimate the size of each particle counted consequently creating a trash frequency distribution. This software has the potential to provide USDA AMS with descriptive trash particle size and distribution for their Trash Under Glass check samples. Research may indicate certain particle sizes optimize textile processing so that USDA AMS could adopt the new software thus making gins cognitive of trash and certain size distributions.

Trash can be identified, sized, and counted but little is known regarding the size indicated by this software and how well it relates to the particles actual size. In order to understand the HVI 900A Trashmeter measurement, Experimental Tiles were created to check generated results. Various sizes of a square and circle were evaluated with the following three measurement techniques 1.) Trashmeter software, 2.) stereomicroscope, and 3.) ImageTool image processing software. The HVI Trashmeter and ImageTool were both capable to consistently count round and square particles 0.01 inches and larger (Table 3). Any total count discrepancies resulted in somewhat higher counts by the software package ImageTool and slightly lower counts for the HVI Trashmeter. ImageTool software was able to accurately count particles 0.002 in diameter. Particles sized smaller than 0.01 inches posed problems for the HVI Trashmeter while all particle sizes could be estimated using the stereomicroscope.

The Trashmeter was only able to locate 92% of particles sized 0.009 inches and 15% of particles sized 0.006 inches. There are variations between particle sizes and the HVI typically overestimates. For the three measurement techniques able to count all particles, ImageTool software appears to predict the particles size with the lowest mean percent difference between size and calculated size. ImageTool software provides a mean difference of 28%, the stereomicroscope provides a mean difference of 40%, and HVI Trashmeter provides a mean difference of 57%. Methods were comparable and demonstrated satisfactory results with similar trends in dimensions. Minor problems exist with any measurement technique and with the current software, extremely low and high amounts of trash may overload the software. This difficulty could be easily handled with minor software programming adjustments. Closeness of trash can become a factor with any image processing and analysis because, as particles approach each other, many single particles morph into one. This problem could be less of an issue by capturing the images at a higher resolution or using an alternative method.

Minimal lint cleaners for the pima cotton appear most efficient for producing the least ends down with roller ginning producing fewer ends down than saw ginning with or without lint cleaners. Cotton that has been roller ginned is typically exposed to a more gentle fiber seed separation process than saw ginning. In this study, this gentle ginning results in cotton that contains trash with a larger mean particle size with or without a lint cleaner (Table 4). Additional lint cleaning reduces the trash particle size for both roller and saw ginning. Shirley analyzed cotton demonstrates additional visible and invisible waste in the saw ginned and roller ginned cotton followed by these processes with lint cleaning. The lack of lint cleaning prevents trash from being removed from the cotton and is observed through a larger sum of trash. A trend appears to exist with the raw upper quartile length (UQL) and short fiber content (SFC) indicating that lint cleaning reduces the fiber length and increases SFC. The amount of raw neps is greatest for saw ginning with any lint cleaning appearing to produce more problematic neps.

Yarn irregularity increases as trash accumulates in the rotor. Fibers cannot accumulate in the narrow portion of the groove so the fibers are less aligned and positioned with the yarn formation erratic, irregular, and weak. Yarn imperfections of thin, thick places and neps increase with increase in trash content. It is likely that the trash particles act as a nucleus for neps during spinning.

The small seed variety with saw guides may produce more ends down than without saw guides while the standard variety demonstrates the opposite trend (Table 4). Small seed varieties appear to produce more ends down than the standard sized seeds. Trashmeter software appears to demonstrate that the mean trash size is affected by ginning. Trash found in the cotton samples appears to be follow a trend with the small seed variety cotton producing smaller trash during ginning and without saw guides producing the smallest trash particles. The sum of trash particles is greatest for small seeds followed by standard seed variety with saw guides. No saw guides produces the lowest sum of trash particles for the standard seed variety. A trend appears to exist with saw guides maintaining the raw UQL for both small and standard seed variety with the smaller seed variety appearing to have the smallest fiber length. The variety of seed may impact the amount of raw SFC with this small seed variety producing the highest raw SFC.

Understanding that the HVI Trashmeter is able to locate and size trash particles has led to its use in evaluating ginning differences, cotton trash types, cotton trash sizes (Table 5), and spinning correlations. In this study, cotton ginned using both a roller and saw gin produced varying degrees of trash in the raw stock, opening and cleaning steps, and contaminants during spinning. All data was normalized so that every variable had a standard normal deviance with a mean of zero and a variance of one. Proc stepwise in SAS was used to determine which of these standardized normal variables were significant in predicting ends down. For this study, the amount of raw stock visible waste generated from the Shirley analyzer, HVI strength, HVI Rd, trash categories 2 (>5≤10 pixels) and 22 (>200≤300 pixels) appear to be the most significant ends down predictor variables at the 0.05 level with a coefficient of determination R^2=0.9919. Subsequent to significant variable determinations, individual scatter plots of these variables were prepared for data visualization. These scatter plots streamline the process for data linearization transformations. Trash category 22 (>200≤300 pixels), raw stock visible Shirley waste, and HVI strength were squared to linearize data. Ends down, trash category 2 (>5≤10 pixels), and HVI Rd was transformed using the log function to again linearize data. Proc GLM in SAS was used to determine an ends down predictor equation. This equation appears to show that the ends down in spinning can be forecast with a coefficient of determination R^2=0.82 if one knows the level of raw visible waste from the Shirley analyzer (grams), HVI strength (grams/tex), HVI Rd, along with trash categories T2 and T22 obtained using the new Trashmeter software (number of particles in respective category). This equation demonstrates the importance of cotton trash in open-end spinning. As the amount of raw visible waste from Shirley analyzing, the number of trash particles, and Rd increases the number of ends down increases.

$$\text{Log (Ends Down)} = 451 - 1.04(\log(T2)) - 0.27(T22)^2 - 0.003(\text{Raw Visible})^2 + 0.12(\text{Strength})^2 - 117(\text{Log}(Rd)).$$

Raw trash changes during processing so that a large portion of this trash is removed and has neither the same shape nor form as trash found in processed sliver. It would be a difficult task to follow a single trash particle from the cotton field, through ginning, and all the way through spinning let alone several million-trash particles. A majority of ends down are due to dust and trash deposits (seed coat fragments frequently considered the culprit). Thus the inspiration to evaluate rotor dust buildup, the common cause of ends down in open-end spinning. Identifying the type of trash producing this rotor dust could improve textile mills efficiency with anticipation that a gin would better remove this trash type. Analysis of rotor dust with mid-IR indicates that rotor dust consists mainly of hull and shale (Table 6), with seed coat fragments not matched within top ten matches. The IR system is currently not entirely able to detect variety differences but with an expanding database of trash samples from many varieties and localities this could potentially be possible. Sample preparation would likely play an important role in better utilizing the generated results. These preliminary results may allow textile mills to better understand types of trash causing processing problems.

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Disclaimer

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Table 1. Official cotton bale classification data.*

Gin[a]	TRASH SPIKED[b]	Mic	Strength	Rd	+b	Trash	UHM	UF	Leaf
1[c]	NO	4.26	38.45	64.67	12.94	11.67	1.33	84.33	4.08
2[c]	NO	4.14	39.39	65.75	13.38	5.42	1.34	84.33	3.00
3[c]	YES	4.42	39.03	63.08	12.93	10.83	1.31	83.33	4.58
4[c]	YES	4.12	39.86	66.75	13.53	3.17	1.30	82.83	3.00
5[d]	NO	3.80	27.97	76.50	8.77	4.08	1.14	79.83	4.42
6[e]	NO	4.59	27.22	74.17	8.66	4.25	1.14	81.17	4.58
7[d]	NO	3.85	27.79	75.08	8.95	4.42	1.13	79.50	4.58
8[e]	NO	4.64	27.94	73.53	8.72	3.97	1.14	81.25	4.17

* USDA, ARS, AMS, Memphis, TN.

[a]Treatment 1 consisted of one cylinder cleaner, roller-gin stand, and zero lint cleaning.
Treatment 2 consisted of cylinder cleaner-stick machine-cylinder cleaner, roller-gin, and Aldrich beater-super jet lint cleaner.
Treatment 3 consisted of one cylinder cleaner, saw-gin stand, and zero lint cleaning.
Treatment 4 consisted of cylinder cleaner-stick machine-cylinder cleaner, saw gin stand, and one saw-type lint cleaner.
Treatments 5 and 6 consisted of a cylinder cleaner-stick machine-cylinder cleaner and saw-gin stand with experimental saw guides.
Treatments 7 and 8 consisted of a cylinder cleaner-stick machine-cylinder cleaner and saw-gin stand without guides.

[b]Spiked with 30 pounds of mostly whole hulls at the gin stand just prior to ginning to represent potential harvests.

[c]Pima variety.

[d]Small seed upland variety.

[e]Standard seed upland variety.

Table 2. Trashmeter check samples of Trash Under Glass tiles to evaluate the effectiveness of new HVI Trashmeter software *

USDA Trash Percent area (%)	USDA Trash Count (no.)	Trashmeter Count[b] (no.)[c]	Mean Trashmeter size[b] (pixel)	Total Trashmeter area[b] (pixel)	Mean trash classification[a] 1 (no.)	2 (no.)	3 (no.)	4 (no.)	5 (no.)	6 (no.)	7 (no.)	8 (no.)
0.15	8	7 a	33 a	243 a	0.7 e	0.7 c	1.0 c	0 b	0.3 c	0.7 a,b	0.2 c	0.2 a
0.26	15	15 b	35 b	512 b	1.8 c,d	3.7 b	3.3 b	1.7 a	0 c	0 c	0.3 c	0.2 a
0.62	23	20 c	56 c	1091 c	1.2 d,e	1.3 c	1.0 c	0 b	1.0 b	0.2 c	1.7 b	0.2 a
0.80	37	36 d	45 d	1603 d	4.5 b	7.2 a	4.8 a	0.3 b	0.8 b	1.0 a	2.2 b	0.2 a
1.00	33	30 e	64 e	1896 e	2.8 c	1.2 c	1.0 c	1.8 a	0 c	0.3 b,c	2.8 a	0 a
1.81	52	50 f	69 f	3394 f	6.2 a	4.3 b	4.2 a,b	2.2 a	1.7 a	0 c	0.2 c	0.3 a

* Check samples of Trash Under Glass tiles produced via a mixture of cotton fibers and trash by USDA, AMS, Cotton Division, Memphis, TN.

[a] Particles located in Trash Under Glass tiles classified into eight size categories using the new HVI Trashmeter software and referred to as 1 (≤5 pixels), 2 (>5≤10 pixels), 3 (>10≤15 pixels), 4 (>15≤20 pixels), 5(>20≤25 pixels), 6 (>25≤30 pixels), 7 (>30≤35 pixels), and 8 (>35≤40 pixels) respectively. HVI Trashmeter has a viewing area of 9 in^2 and 1 square inch is approximately equal to 14,363 pixels.

[b] HVI Trashmeter cotton quality trash measurements were performed using a HVI 900A (Zellweger Uster, Knoxville, TN) by the Testing Laboratory at CQRS.

[c] Values followed by different letters within columns are significantly different, P<0.05, according to Duncan's New Multiple Range Test.

Table 3. Experimental Tiles created to simulate trash particles and evaluate effectiveness of new HVI Trashmeter software.*

Particle Shape[a]	Particle Size[a] (in)	Particle Count[b] (no.)	Particle Total Area[b] (in^2)	IT Count[c] (no.)	HVI Count[d] (no.)	IT Blob Mean Size[c] (in)	Micro Blob Mean Size[e] (in)	HVI Blob Mean Size[d] (in)	IT Total Area[c] (in^2)	Micro Total Area[e] (in^2)	HVI Total Area[d] (in^2)
Circle	0.002	128	0.00040	129	error	0.0053	0.0089	error	0.0043	0.0082	error
Circle	0.003	96	0.00068	97	error	0.0056	0.0078	error	0.0035	0.0049	error
Circle	0.004	128	0.0016	128	0.4	0.0064	0.0095	0.0010	0.0058	0.0093	8.35E-05
Circle	0.005	96	0.0019	97	0.2	0.0083	0.011	0.00036	0.0064	0.0085	4.18E-05
Circle	0.006	128	0.0036	131	19.7	0.0097	0.014	0.017	0.012	0.020	0.0047
Circle	0.007	96	0.0037	96	88.8	0.011	0.015	0.019	0.011	0.017	0.028
Circle	0.008	128	0.0064	132	98.9	0.012	0.016	0.019	0.017	0.025	0.029
Circle	0.009	96	0.0061	97	88.8	0.013	0.020	0.020	0.015	0.029	0.028
Circle	0.01	160	0.013	161	160	0.015	0.020	0.022	0.031	0.049	0.064
Circle	0.02	128	0.040	128	128	0.023	0.030	0.033	0.055	0.091	0.11
Circle	0.04	96	0.12	96	96	0.044	0.058	0.056	0.14	0.25	0.24
Circle	0.08	64	0.32	64	64	0.084	0.086	0.096	0.35	0.37	0.46
Circle	0.16	32	0.64	32	32	0.16	0.17	0.17	0.67	0.72	0.75
Square	0.01	160	0.016	163	158	0.015	0.019	0.022	0.031	0.062	0.062
Square	0.02	128	0.051	131	128	0.028	0.031	0.038	0.072	0.13	0.14
Square	0.04	96	0.15	101	96	0.054	0.056	0.061	0.18	0.33	0.28
Square	0.08	64	0.41	64	64	0.11	0.086	0.11	0.45	0.41	0.57
Square	0.16	32	0.82	35	32	0.21	0.17	0.19	0.85	0.90	0.95

[a] Tile sets were generated using TurboCAD Professional version 7 and printed on acid-free HammerMill pastel cream 67 lb cover stock using a Hewlett Packard LaserJet 1100A at 600 dpi. Each individual experimental tile consisted of particles uniform in size and distribution.

[b] Particles on Experimental Tiles were visually counted with area calculated.

[c] Experimental Tiles were scanned at 600 dpi using a HP OfficeJet G85 scanner. These scanned images were imported and analyzed using UTHSCSA ImageTool version 3 (free image processing and analysis program developed at the University of Texas Health Science Center at San Antonio, Texas and available from the Internet by anonymous FTP from maxrad6.uthscsa.edu).

[d] HVI Trashmeter cotton quality trash measurements were performed using a HVI 900A (Zellweger Uster, Knoxville, TN) by the Testing Laboratory at CQRS.

[e] Diameters or side lengths of all particles in all Experimental Tiles were achieved by visual measurements on a Zeiss Stemi SR stereomicroscope at 50X magnification.

Table 4. Cotton trash and spinning performance.

Gin[a]	Ends Down[b]	Mean Trash[c]	Sum Trash[c]	Raw VFM	Raw Neps	Raw SFC	Raw Visible	Raw Invisible	Card Visible	Card Invisible
1	469 c	34.7 a	4101 a	2.4 b,c	111 e	6.0 e,f	7.5 b	2.1 a	30 a	5.5 b
2	846 a	28.5 b	1920 b	1.7 c	142 e	5.7 f	3.7 c	1.4 c	23 a,b	6.2 b
3	304 d	28.3 b	3916 a	6.3 a	271 b	6.7 d,e,f	14.3 a	2.2 a	17 a,b	24.5 a
4	742 b	17.0 c	920 c	2.6 b,c	332 a	7.6 c,d,e	3.9 c	1.4 c,d	23 a,b	13.5 a,b
5	299 d	17.8 c	4642 a	3.3 b	238 b,c	10.3 a,b	3.4 c	1.5 b,c	14 a,b	9.9 a,b
6	91 e	19.0 c	4638 a	3.2 b	216 c,d	8.8 b,c	2.8 c	1.1 d	22 a,b	5.7 b
7	126 e	16.9 c	4605 a	3.1 b	261 b	11.0 a	3.6 c	1.7 b	6.8 b	10.5 a,b
8	134 e	17.8 c	4207 a	2.9 b,c	185 d	7.9 c,d	3.5 c	1.6 b,c	1.2 b	5 b

[a]See Table 1 for ginning treatments.

[b]Ends-down recorded during open-end yarn production on a Schlafhorst SE-11.

[c]HVI Trashmeter cotton quality trash measurements were performed using new HVI Trashmeter software on a HVI 900A (Zellweger Uster, Knoxville, TN) by the Testing Laboratory at CQRS. HVI has a viewing area of 9 in^2 and 1 square inch is approximately equal to 14,363 pixels.

Table 5. Raw cotton stock showing trash particle distribution*.

		Trash classification [a]																								
Gin[b]	ED[c]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	469 c	28 b,c	25 c,d	15 c,d	8 b,c	7 b	6 b	3 c,d	2 b	3 b,c	2 b,c	2 a,b	2 a	1 b,c	1 a,b	1 a,b	1 a,b	1 a	0 a	1 a	0 a,b,c	5 a	1 b,c	1 a	0 a	1 a
2	846 a	18 c	16 d	9 d,e	7 b,c	3 c	3 c	2 d,e	2 b	1 c,d	1 b,c	1 c	1 a	1 c	1 a,b	0 a,b	0 a,b	0 a	0 a	0 a	0 b,c	1 a	2 b,c	0 b	0 a	0 b
3	304 d	34 b	31 c	18 c	12 b	8 b	6 b	5 b,c	3 b	2 b,c	3 a,b	2 a,b	2 a	1 a,b,c	1 a,b	1 a,b	1 a,b	1 a	1 a	1 a	1 a,b	5 a	1 a,b,c	0 a,b	0 a	0 a,b
4	742 b	17 c	14 d	7 e	5c	3 c	2 c	1 e	1 b	0 d	1 d	0 c	1 a	0 c	0 b	1 a,b	0 b	0 a	0 a	0 a	0 c	1 b	0 c	0 b	0 a	0 b
5	299 d	72 a	72 a,b	36 a,b	22 a	15 a	9 a	7 a,b	6 a	5 a	3 a,b	1 b,c	2 a	2 a	1 a,b	1 a	1 a	0 a	2 a	1 a	0 a,b,c	3 a,b	2 a	1 a,b	0 a	0 b
6	91 e	66 a	65 a,b	35 a,b	21 a	14 a	10 a	7 a	5 a	5 a	4 a	2 a,b	2 a	1 a,b,c	2 a	1 a,b	1 a	1 a	1 a	1 a	1 a	4 a,b	1 b,c	0 b	0 a	0 b
7	126 e	78 a	76 a	38 a	23 a	14 a	11 a	6 a,b	6 a	4 a,b	3 a,b	2 a,b	2 a	2 a	1 a,b	1 a	0 a,b	1 a	1 a	0 a	0 a,b,c	2 a,b	1 a,b,c	0 a,b	0 a	0 b
8	134 e	68 a	62 b	29 b	21 a	13 a	10 a	7 a	5 a	4 a,b	4 a	3 a	1 a	2 a,b	1 a,b	1 a,b	0 a,b	1 a	1 a	1 a	1 a	3 a,b	0 c	0 a,b	0 a	0 b

* HVI Trashmeter cotton quality trash measurements were performed using a HVI 900A (Zellweger Uster, Knoxville, TN) by the Testing Laboratory at CQRS.

[a]Trash classification using the new HVI Trashmeter software and referred to as 1 (≤5 pixels), 2 (>5≤10 pixels), 3 (>10≤15 pixels), in 5 pixel increments until category 21 (>100≤200 pixels), 22 (>200≤300 pixels), 23 (>300≤400 pixels), 24 (>400≤500 pixels), and 25 (>500 pixels) . Note HVI has a viewing area of 9 in^2 and 1 square inch is approximately equal to 14,363 pixels.

[b]See Table 1 for ginning treatments and official USDA AMS cotton bale classifications.

[c]Ends-down recorded during open-end yarn production on a Schlafhorst SE-11.

Table 6. Cotton rotor dust mid-infrared spectroscopy database classification.

Gin[a]	Rep	TRASH SPIKED[b]	Top 5 matches[c] 1	2	3	4	5	Ends down
1	1	NO	HSP	HIP	HVP	HIP	HOP	497
1	2	NO	HSP	HIP	HVP	HIP	HV	465
1	3	NO	HSP	HIP	HVP	HIP	BRACT	445
2	1	NO	HSP	HIP	HVP	HIP	HV	794
2	2	NO	HSP	HIP	HVP	HIP	HV	883
2	3	NO	HSP	HIP	HVP	HIP	HV	861
3	1	YES	HSP	HIP	HVP	HIP	HS	304
3	2	YES	HSP	HIP	HIP	HVP	HVP	301
3	3	YES	HSP	HIP	HVP	HIP	HV	309
4	1	YES	HSP	HIP	HVP	HIP	HV	704
4	2	YES	HSP	HIP	HVP	HIP	GRASS	734
4	3	YES	HSP	HIP	HVP	HIP	GRASS	787
5	1	NO	HV	SI	SV	SV	SI	167
5	2	NO	HVP	SI	SV	SV	HV	431
5	3	NO	HVP	SI	SV	SV	HO	300
6	1	NO	HO	HVP	SV	SV	SV	106
6	2	NO	HO	SV	SV	SV	SV	97
6	3	NO	HO	HO	SV	SV	SV	69
7	1	NO	HV	SV	SV	SV	SI	128
7	2	NO	HV	SI	SV	SV	HO	167
7	3	NO	HV	SV	SI	SV	HO	83
8	1	NO	HV	HO	SV	SV	SV	139
8	2	NO	HV	SV	SV	SV	HO	153
8	3	NO	HV	SV	SV	HO	SV	111

[a]See Table 1 for ginning treatments and official USDA AMS cotton bale classifications.
[b]Spiked with 30 pounds of mostly whole hulls at the gin stand just prior to ginning to represent potential harvests.
[c]Rotor dust was collected and analyzed by mid-infrared spectroscopy and compared to a spectral database of authentic samples denoted by the following abbreviations: HVP, Hull Vein (Pima); HIP, Hull Inside (Pima); HOP, Hull Outside (Pima); SVP, Shale Vein (Pima); SIP, Shale Inside (Pima); HSP, Hull Stem (Pima); HV, Hull Vein (Upland); HO, Hull Outside (Upland); HI, Hull Inside (Upland); SV, Shale Vein (Upland); SI, Shale Inside (Upland); HS, Hull Stem (Upland); BRACT; and GRASS.
[c]Ends-down recorded during open-end yarn production on a Schlafhorst SE-11.

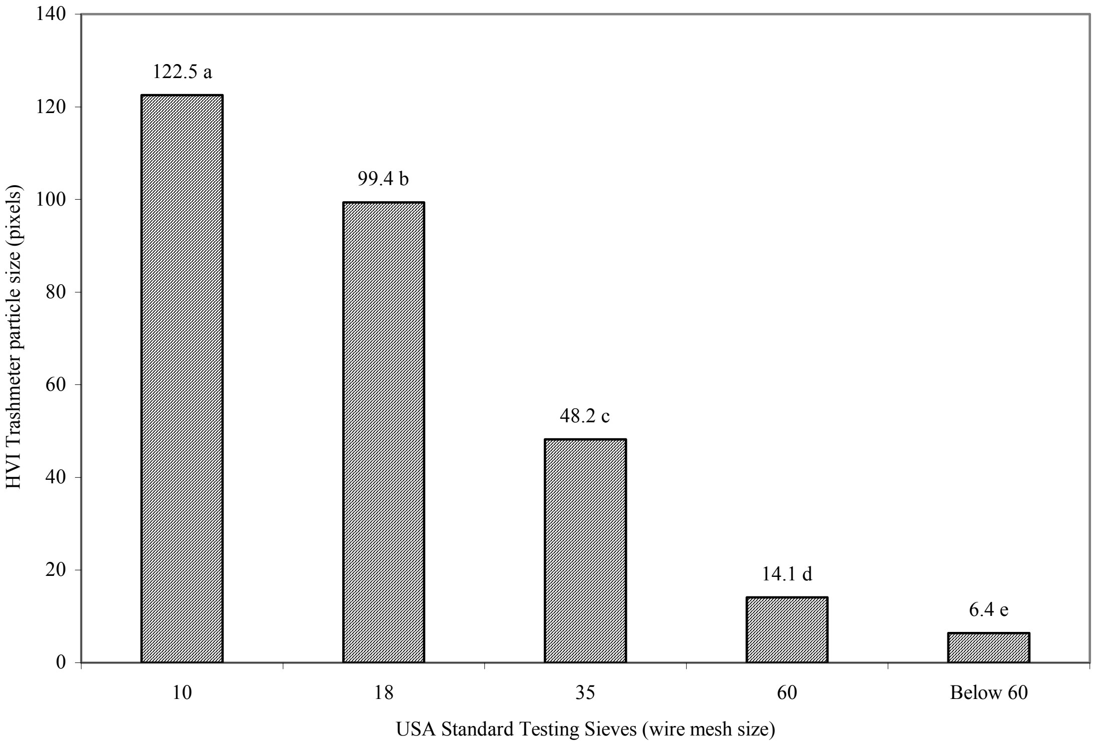

Figure 1. Trashmeter results for trash particles sieved through USA Standard Testing Sieves containing wire mesh size of 10, 18, 35, and 60 with respective mesh openings of 0.0787 in, 0.0394 in, 0.0197 in, and 0.0098 in. The smallest trash particles that passed through all mesh opening were collected in a collection pan in series. HVI Trashmeter has a viewing area of 9 in^2 and 1 in^2 is approximately equal to 14,363 pixels.