2003 BELTWIDE COTTON CONFERENCES, NASHVILLE, TN – JANUARY 6-10

RISK ASSESSMENT OF CONTAMINATION POTENTIAL OF POLYOLEFIN BALE BAGGING

Andrew G. Jordan
National Cotton Council of America
Memphis, TN

Abstract

Contamination from non-cotton fibers can interfere with spinning, weaving and knitting and cause defects in cotton textile fabrics. Speculation that the bale package is a source of contamination led to risk evaluation of woven polyolefin fabrics on cotton bales. Woven polyolefin fabrics (primarily polypropylene) have been used in the construction of bale bagging for US cotton bales for more than 30 years and have been applied to an estimated 250 million bales. The objective of this report is to summarize exposure analysis and dose-response spinning studies and put results of those studies in context of industry experience. The report concludes the risk of contamination from woven polyolefin bale bagging manufactured and used in accordance with industry specifications is virtually zero.

Introduction

The focal point of the US cotton industry's goal of maintaining lint purity in cotton bales is the Joint Cotton Industry Bale Packaging Committee (JCIBPC). The JCIBPC membership consists of cotton producers, commercial ginners, shippers, warehousers and textile manufacturers. Each group represents a stakeholder interest in the effective and efficient packaging of US cotton bales. Since 1967 the US government has adopted detailed bale-packaging specifications from the JCIBPC and made the specifications as part of the USDA regulations for CCC loan eligibility.

Contamination in Textile Products

Worldwide, lint contamination is a multi-million-dollar textile problem. Because of cotton's multiple exposure to vagaries of field production, harvesting, seed-cotton storage, ginning, warehousing and transportation, raw cotton lint can contain contamination. Articles of apparel, industrial fabrics, plastic twine, ropes, roadside litter, torn bagging, contaminated transportation equipment and poor housekeeping in mill opening rooms represent potential contamination sources.

Heightened awareness of the economic hazards of contaminated cotton has been the subject of coordinated campaigns led by the National Cotton Council. Cooperators in the educational efforts are National Cotton Ginners, Cotton Incorporated, USDA Extension Service and Southern Cotton Ginners. These efforts have aided the US cotton industry to earn a reputation as a reliable supplier of contamination-free cotton.

Despite advances the industry receives periodic reports of contamination from textile spinners. Because the industry goal is zero defects, each episode is evaluated to assist in focusing future efforts.

Bale Packaging

An important line of defense against contamination is the proper packaging of cotton bales. For more than 30 years the US cotton industry has developed its own industry-wide packaging standards for packaging materials. Annually the USDA has adopted the specifications as recommended by the JCIBPC as a US government requirement for any bale to be eligible to serve as collateral for USDA/CCC loan. The JCIBPC provides the mechanism for review and approval. Having all major stakeholders—growers through spinners—involved in approving packaging specifications, the JCIBPC procedure assures optimum selection of materials. As an extra measure of protection for textile interests, US textile mill representatives on the JCIBPC are allowed veto privileges on approval of all packaging specifications, a provision that assures textile interests are protected. Textile mill members of the JCIBPC typically have represented over 70 percent of US cotton textile consumption.

Historically, the first approved packaging materials consisted of coarse-yarn jute bagging weighing 12 pounds per each cotton bale (two sheets) and hot-rolled steel bands weighing 9 pounds per bale. In those early days of official specifications for cotton bale packaging, package dimensions and weight were effectively the limit of technical requirements. By providing a mechanism for formalizing specifications, innovation in the form of modern packaging, manufacturing, automation, and materials handling systems was encouraged.

In 1976 the JCIBPC adopted the use of woven polypropylene (wpp) bale cover. Approval was made after six years field-testing, evaluating performance at all points along the processing, marketing and handling chain. Evaluation involved monitoring performance at cotton gins, warehouses and compresses within transportation systems, the most critical evaluation being made at textile mills. More than 200,000 bales were involved in the experimental bale test program.

In addition to monitoring field experiences by the JCIBPC, commercial textile mills conducted their own contamination tests prior to approval. Examination of NCC file reports from 1975 report that three commercial textile mills conducted tests by adding polypropylene yarns to cotton prior to carding and examined yarn and fabric quality. No defects were reported in any of the tests. Though these tests gave evidence to demonstrate to the JCIBPC that wpp did not present unreasonable risk, the industry, nevertheless, continued to monitor performance.

Some spinners not familiar with the extensive process of approval, expressed serious concern about wpp use as a bale cover. Intuitive reasoning has led many to believe that torn wpp bagging as a source of defects. This idea is perpetuated due to the high visibility of bale bagging in contrast to the virtually invisibility of contaminants that may be hidden deep within the layers of cotton bales.

Incomplete laboratory analysis also contributed to inaccurate conclusions. The author has observed on numerous occasions, the following typical scenario in which textile plants seek to identify the cause of a contamination episode: When cotton fabric defects were noted, laboratory technicians began by conducting a thermal or chemical qualitative test. If tests revealed the contaminant was of olefin resin, then the analysts assumed that the problem originated from bagging. Even though wpp is near translucent, the most prevalent contaminants were heavily pigmented with black, red, orange or blue colors.

By the early 1980s, millions of US bales covered in wpp had been processed with no substantive evidence that the wpp bagging was a significant source. Nevertheless, strong opinions persisted, and resulted in numerous demands to disqualify wpp as an approved bagging. While nearly all agreed that it is possible for virtually any plastic material to become a contaminant, there was a need to better describe the degree of risk.

The National Cotton Council staff under auspices of the JCIBPC directed several studies to better quantify risks. Data reported in this paper were collected from laboratory reports, field notes, files and records of the National Cotton Council.

Exposure Studies

The first step in risk analysis was to quantify exposure, that is, the amount of loose pieces of bagging that could become mixed with cotton before processing. In 1980 the Georgia Tech Textile Engineering Experiment Station was contracted to lead an exposure study to determine how much bagging potentially can be left on the bale surface in the mill opening room. Three commercial textile mill-opening rooms and 184 bales of cotton were involved in the study. Study protocol required that opening room personnel remove only the primary bale cover leaving any yarn fragments and fabric remnants on the bale. Next the researcher carefully gleaned all bale surfaces, collecting and weighing potential bagging contaminants. Most polypropylene strands were found where bale covers were cut for access to cotton samples.

The median weight of materials left on the bales in this study was 0.123 grams per bale. The range was 0 to 5.88 grams and the average was 0.299 grams per bale. For purposes of risk prediction, the median weight is used in calculations. Average values were considered inappropriate because of heavy bias introduced by a few large remnants of large pieces of fabric that ranged from 50 to 100 square inches each. It is reasonable to expect that grossly large pieces will be removed even in the most lax of mill opening rooms. Having determined exposure values, the next process was to conduct research to quantify the dose-response relationships.

Risk Analysis in Ring Spinning Textile Processing System

Processing trials were conducted in 1980 at the USDA Cotton Quality Research Laboratory, Clemson South Carolina. Experiments were designed to determine a dose-response relationship of wpp and fabric defects in a ring spinning system. Dose-response is described as the predicted response (processing difficulties and yarn defects) when a certain dose (pieces of wpp) is mixed with cotton. In this study, measured amounts of polypropylene yarns were added to known weights of cotton and processed on the pilot plant cotton spinning system.

Polypropylene yarns used in these treatments had all physical properties as commercial yarns with one exception. Yarns were highly pigmented with either bright red or bright blue colorants. The bright colors facilitated inspection for defects.

Two grams each of a red and blue polypropylene yarn were randomly mixed with 100 pounds cotton (4 grams wpp per 100 pounds cotton) prior to opening and blending. The contaminant/cotton concentration was more than 160 times the median amount typically left on uncleaned bale surface.

To further determine whether there was a difference between fibrillated or intact yarns in their likelihood to become contaminants, the blue yarns were ruptured (fibrillated) to an average length of 3 inches in an Instron tensile testing machine. The red yarns were cleanly cut to random lengths ranging from 1 to 4 inches. A control treatment with no added contaminants was included in the study.

Spinning Breaks

The card sliver was processed through drawing, roving and ring spinning. Yarns having a twist multiple of 3.88 were spun into 25/1 yarns. Yarn breaks as measured in ends-down-per-thousand-spindle-hours (EDMSH) increased from an average of 32 EDMSH for the control compared to 153 EDMSH for the treatments. Means of control and treatments were statistically different 0.05 level. There was no statistical difference separating means of red defects and blue defects.

Normalizing these data to the median exposure level, the:

Increase in EDMSH	=[EDMSH (Contaminated) – EDMSH (control)] ÷concentration factor
	=(153 – 32)/ 162
	=0.77 EDMSH

Fabric Analysis

Yarns produced during the spinning study were knitted into a circular knit fabric. A fabric sample of 75 yards representing 17.2% of the total treatment was evaluated. The red and blue polypropylene pieces in fabric were counted on a backlighted inspection table at a commercial textile mill. The mill director of quality control and the author made evaluation. Red and blue defects were counted separately.

Fabric inspection revealed 66 red and 67 blue defects in the treatment lots while none were found in the control. The fact that the number of blue and red flaws was virtually the same indicates that the propensity to contaminate seems to be unrelated to whether a yarn is fibrillated or smoothly cut.

Dose Response Calculations

Defects counted in the 75 yard fabric sample (17.2% of total) was extrapolated to the original 100 pounds cotton in the treatment.

Dose-response	=133 defects/ (4 grams wpp x 0.172)
	=193 defects per gram polypropylene

Exposure Prediction - Defects/Pound Cotton

Contamination factor is the concentration of contamination in relation to median bale exposure.

Contamination factor	=treatment concentration/commercial bale concentration
	=[4 g/100 lbs. cotton]/[0.123 g exposure/500lbs.]
	=162
Defects/pound cotton	=defects per gram pp/lb. cotton ÷contamination factor
	=((66+67)/15.5 lbs.)÷ 162
	=0.053 defects /lb.

Exposure Frequency - Square Yards/Defect

Yards 5-ounce cotton fabric/defect	=[1/0.053] x 16 oz/lb/5oz fabric
	=60 square yards/ defect

In real world terms, in a 5 ounce / square yard fabric, un-cleaned bale, an increase in defects of one defect per 60 square yards is predicted.

Risk Analysis in Open End Spinning System

In 1984, research was conducted to evaluate risk potential of wpp yarns in an open end spinning system. The Georgia Tech Textile Engineering Experiment Station in collaboration with the USDA/ARS Cotton Quality Research Laboratory in Clemson SC directed Work.

Six lots of cotton fiber each weighing 70 pounds, were processed into sliver in the cotton staple system at Clemson. One gram of red and 1 gram of blue yarns were added to each of the three treatment lots. Three lots receiving no contaminants served as controls. Red yarns were fibrillated to an average length of 3 inches. Blue yarns were cut in variable lengths from 1 to 6 inches with each length category having the same mass. The ratio of polypropylene yarns to cotton represented a concentration factor of 230 times the normal expected concentration.

Slivers in cans were transported to the Georgia Tech Textile Engineering Experiment Station in Atlanta, Ga. The six lots were run on the open-end spinning frame of the laboratory producing 11/1 yarns with a rotor speed of 30,000 rpm. Run time was 5.5 hours.

Ends Down in Rotor System

Average ends down (ends-down per thousand rotor hours, EDMSH[1]) for the treatment lots was 333 EDMSH whereas the ends-down for the control lots averaged 96 EDMSH. Increase of 237 EDMSH was statistically different form the control at 0.05 level. Applying the concentration factor of 230, the predicted ends down from a typical uncleaned opening room would increase approximately one EDMSH.

Increase in EDMSH =[EDMSH (Contaminated) – EDMSH (control)] ÷concentration factor
=(333 – 96)/ 230
=1.03 EDMSH

Fabric Contamination

All of the treatment yarns were knitted into circular knit fabric and inspected. The full length of each fabric roll was inspected. A total of 353 defects caused by red yarns (51 defects per gram wpp) and 500 from the blue yarns (83 defects / gram wpp) were counted. The fact that a larger number of blue defects were found indicates that cleanly cut yarns may represent more of a risk than fibrillated yarns. However, blue yarns had greater variation and means of red and blue were not statistically different at the 0.05 level.

Dose-response =853 defects/ 6 grams wpp
=142 defects per gram wpp

Risk Analysis by Cooperation Mill

A cooperating textile mill conducted an independent study in 1983. The primary purpose was to determine if there is a color change in polypropylene during fabric finishing. The study was prompted by the supposition that heat and processing chemicals would cause the translucent polypropylene resins to turn black. A secondary purpose was to determine a dose/response relationship.

In this study 3 grams of polypropylene yarns 1 to 3 inches long were added to 25 pounds of blended polyester/cotton lint. The concentration level was 480 times greater than median exposed bale.

Filling yarn was processed and inserted in the warp of a production run of 7.5-ounce/square yard twill fabric. Fabric was dyed olive green and finished in normal drying and pressing procedure for this style. The finished fabric was inspected for defects. No evidence was found that the polypropylene turned black however, the defects were partially melted and resulted in light colored undyed specks.

Approximately 100 linear yards were woven from the 25 pounds of lint represented in the fill yarns. Thirty-four defects were counted in a 13 linear yard sample of fabric. The 13-yard sample represented 13/100 or 13% of total production run of this treatment. Extrapolating to the entire treatment lot,

Dose response =34 defects / (3 grams wpp x 0.13)
=104 defects / gram wpp.

The dose response relationship of 104 defects/gram wpp is approximately one-half that determined in the laboratory ring spinning study and study and about 50% less than the levels found in the open end study.

---

[1] Yarn breaks units of EDMSH for both ring and rotor-spinning systems are used throughout this paper.

Summary of Dose Response Studies

Studies provided a reliable framework to predict a range of contamination levels under extreme conditions. Results are summarized in the table 1. Under the conditions of these tests, ring spinning indicated the most severe defect level at one expected defect in 38 square yards of 8 ounce per square yard fabric. Commercial trials indicated the risk at approximately one-half expected under laboratory conditions. Recognizing the severity of tests, the JCIBPC deemed levels acceptable. Nevertheless additional measures were taken later by industry to further reduce risks.

Discussion

These trials evaluated levels assuming high exposure, that is, no cleaning at textile mill. Using these data as a baseline, it was reasonable to expect that subsequent steps taken by the industry to mediate exposure would decrease risks even further.

Tests reported in this paper were completed in 1984,and since that time, the industry has implemented several steps to further reduce probabilities of contamination. They are: (1) In 1985 the JCIBPC changed specifications of wpp bagging to require a fabric stabilization system of coatings or strip-laminations. This first and most significant change decreased potential exposure from 75 to 90% (2) Advances in packaging systems through modernization of gins and attrition, eliminated bale recompression at warehouses—an estimated 50% reduction in exposure, (3) The typical industry practice of cutting multiple sample holes through bagging was stopped. The number of sample cuts were reduced from an estimated average of more than 4 sample holes per bale to less than one—estimated exposure reduction is 75%, (4) and trade practices have been adopted using an industry guide on minimum bale standards which minimizes torn or cut bagging—no numerical estimate is made, but experts deduce that the improvement is significant, and (5) an increase in use of film and fully laminated bagging from about 20% in 1983 to about 35% in 2002—estimated reduction of exposure ranges from 10 to 20%.

Assuming improvements are additive then collective reduction in exposure are estimated to be reduced 96 to 99% from the pre-1984 levels.

National Cotton Council Experiences

Since its inception the National Cotton Council (NCC) has placed high priority on bale purity, especially assuring quality bale packaging standards. As the focal point of industry information, NCC staff has been in a unique position to observe and investigate on lint contamination episodes. Six staff professionals at various times in their career have had direct responsibility for investigating contamination reports from textile mills. Not one can give witness to a verifiable and economically significant contamination episode related to US bagging during a period spanning more than 30 years. Considering the weight of the evidence supported by laboratory testing, monitoring by staff professionals, and history of many years successful use, the risk of contamination of wpp meeting specifications of US cotton industry is proven to be virtually non-existent.

Table 1. Expected defect frequencies of ring and open end spinning laboratory trials and commercial trials calculated at median exposure levels.

	Ring Spinning Trials	**Open End Trials**	**Commercial Trial**
Pounds cotton in treatment (Cotton/polyester blend for commercial trial)	100	70	25
Grams wpp added to treatment	4	6	3
Concentration factor (Concentration experimental treatment/concentration in median uncleaned bale)	162	237	480
Defects per gram wpp	193	143	104
Predicted increase in EDMSH	0.8	1.0	na
Predicted defect frequency in 8 ounce/ square yard cotton fabric	1 in 38 yds.	1 in 50 yds.	1 in 70 yds.
Predicted defect frequency in 4 ounce/ square yard cotton fabric	1 in 75 yds.	1 in 100 yds.	1 in 140 yds.