FINDINGS OF AN INVESTIGATION INTO THE REMOVAL OF PLASTIC WRAP DURING GINNING AND TEXTILE PROCESSING

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Abstract

Contamination in cotton, even if it is a single foreign fiber, can lead to the downgrading of yarn, fabric or garments, or even to the total rejection of an entire batch and can cause irreparable harm to the relationship between growers, ginners, merchants and textile and clothing mills. Contamination thus continues to be a very important cotton fiber quality parameter in the production pipeline, with countries and cotton that are perceived to be contaminated heavily discounted. At the same time spinners are implementing various methods to detect and eliminate contamination. The release and rapid uptake of the John Deere harvesters that produce round modules covered with multiple layers of plastic, is of concern to the ginning, marketing and textile processing industries because plastic presents a serious contamination risk. There is evidence that at times not all the plastic is removed in the module feed area resulting in plastic fragments broken up during ginning and contaminating bales. Contamination is a serious issue as it creates harm to the reputation of a growth. Two trials were conducted with full bales of cotton that were deliberately contaminated and processed through CSIRO's full-scale cotton and textile processing mill to investigate the consequence of plastic contamination on textile processing performance and yarn and fabric quality. The trials showed that the blow room removes very little plastic, whereas the carding processes removed on average 50% of the plastic. However, the carding process also fragments the plastic pieces further thereby contaminating yarns and fabric produced by the ring and rotor spinning systems. Due to their size and color, these plastic fragments only become visible after dyeing leading to inevitable financial claims and losses.

Introduction

Due to the increasing demands of modern spinning, in terms of speed, automation and raw material cost and the increasingly competitive global textile market, cotton fiber quality is of the utmost importance to the spinner. In addition, the presence of contaminants in the cotton, particularly foreign fiber, can greatly affect its perceived quality and value. Various sources of contaminants, such as paper, plastic, feathers etc. can be incorporated into the bale as a result of human interaction during harvesting, ginning and baling, and even in the spinning mill itself (van der Sluijs 2007a, van der Sluijs 2007b, van der Sluijs 2009). This contamination, even if it is a single foreign fiber, can lead to the downgrading of yarn, fabric or garments, and/or even to the total rejection of an entire batch, resulting in large financial claims and losses, which can cause irreparable harm to the relationship between growers, ginners, merchants and textile and clothing manufacturers. Depending upon its nature, spinning and fabric processing method and route as well as the end use, contamination can adversely affect textile processing efficiencies, due to end breakages during yarn and fabric formation, cause damage to processing equipment (such as beaters and wire), and even cause fire in the mill. More importantly, contamination can adversely affect the appearance of the yarn, fabric and final product (Hunter 1989, Schlichter and Loesbrock 1997, Narkhedkar and Lavate 2011, Biermann 2018), especially in fine count yarns (Haldermann and Keller 1992), resulting in such products having to be sold as seconds.

In the light of the above, it is not surprising that there are serious penalties for contaminated cotton (Anon 2007). In 2002, the International Textile Manufacturers Federation (ITMF) reported that claims, due to contamination in cotton, amounted to between 1.4 and 3.2% of total cotton and blended yarn sales. Recognizing the slim margins on which spinning mills operate, these figures illustrate the serious affect which contamination has on spinning mill profit margins (Strolz 2002). The issue of contamination is nothing new, and spinning mills have for a long time lodged complaints and produced evidence of contamination found in cotton bales they have purchased, with the first recorded official complaint raised as far back as 1909 (Anon 1909). Indeed, there is a feeling amongst mills, which is borne out by the ITMF Contamination Surveys, that contamination is increasing and that the cotton trade (growers through to merchants) has done little to eliminate or reduce the incidence of contamination (Schoeller and Blum 2000, Anon 2017). There are, however, no established international or universal standards relating to contamination size and frequency, most end-users demanding a zero level of contamination. As a consequence, the more quality conscious spinners have defined their own allowable levels of contamination, and developed a range of screening protocols in order to assess the contamination risk associated with the various sources or origins of cotton (Patodia 2003, Strolz 2004, Anon 2006).

The weight of contaminants in cotton bales can range from 1 to 100 grams/ton with contamination rates of 1-4 grams /ton considered low, 5-15 grams/ton moderate and above 20 gram/ton as high (Anon 2007, Estur 2008). It has been suggested that, if the level of contamination is less than 1 gram/ton, and all other remediation controls are in place, the contamination in fabric and garment would be minimal. Although, at 0.001% by weight, such level of contamination appears to be extremely small, it must be remembered that contamination is quantified by the number and frequency of incidents, rather than by their weight, and 0.001% by weight can equate to as many as 15,000 fibers (Vijayshankar 2006, Anon 2008, Sharma 2014).

Because of the global cotton industry's growing concern about contamination, and in order to quantify the type and level of contamination found in cotton, the ITMF has, since 1989, conducted biennial contamination surveys of cotton users (mills) to obtain a measure of the level and type of contamination in world cotton crops. The survey shows that across all growths, the incidence of contamination, increased steadily from 14% of all bales surveyed in 1989 to 26% in 2003, followed by a decrease to 22%, stabilizing at this level between 2005 to 2009. This was followed by a slight increase to 23% in 2011, a further increase to 26% in 2013 and then a reduction to 23% again in 2016 - see Figure 1. What is notable is the dramatic increase in contamination worldwide from 1993, which is attributed to spinners becoming more aware of contamination, as the number of complaints received from fabric and garment manufacturers increased, as well as consumers becoming more quality conscious (Anon 2017). Another reason could also be that, increasing automation and the subsequent reduction in labor, led to reduced human vigilance and opportunities to detect and eliminate contaminants, specifically in the ginning and spinning mills (Hunter 1989, Herber, Mayfield et al. 1990, Van Nimmen and van Langenhove 1998, Hamilton, Thoney et al. 2012). A further reason could also be that the installation of automatic detection systems in the spinning mills provided more accurate information on the type and frequency of contamination.

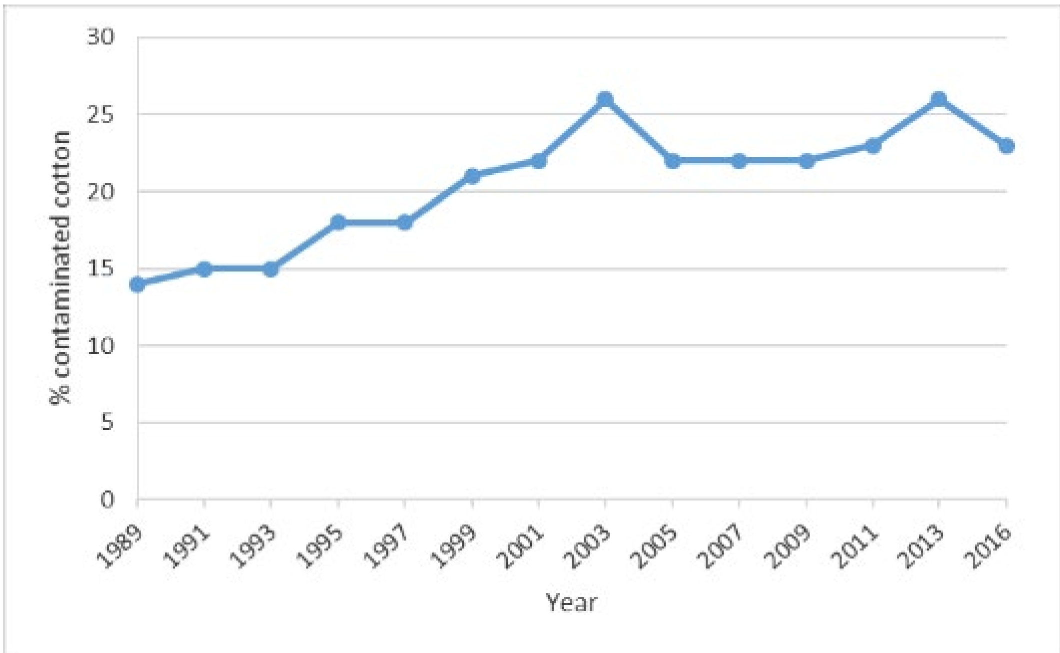

Figure 1 ITMF Contamination survey results from 1989 to 2016 (Anon 2017)

The major source of contamination, in all cotton bales, continues to be organic matter, such as leaves, feathers, paper and leather, which has steadily increased from 30% in total in 1989 to a high of 55% in 2013, then decreasing to 47% in 2016. The next most prevalent contaminants are pieces of fabric and string made from woven plastic and plastic film, followed by jute/hessian, which originate from bale covers and picking bags and cotton both natural and colored, mainly from bale covers but also from apparel, cleaning rags and module ropes. This is followed by inorganic matter, such as sand/dust, rust and metal wires, which are followed by oily chemical substances, such as grease and oil, mainly due to excess lubrication, worn seals and hydraulic oil leaks during harvesting and ginning, stamp color (mainly due to using permanent markers to identify modules or bales) rubber and tar. The incidence of oily chemical substances and inorganic matter, such as rust and metal, has remained fairly constant since 1989. Fabric and string contaminants mainly originate from module covers for both conventional and round modules, plastic shopping and fertilizer bags, agricultural mulch film, plastic twine, irrigation tubing and to a large extent bale covers, which are damaged during warehousing and shipping (Blomquist 1997, Simpson 1998, Van Nimmen and van Langenhove 1998, Jordan 2004).

The incidence of plastic contaminants is becoming a major problem in countries such as Australia and the US, as well as in other countries which have adopted the new John Deere spindle and stripper harvesters which produce round modules covered with plastic wrap (van der Sluijs and Krajewski 2015, Haney and Byler 2017, Whitelock, Byler et al. 2017). Each round module is wrapped with a total of 21 meters of plastic which comprises three layers; beige, yellow and translucent yellow to form the module - see Figure 2 for image of a John Deere harvester with round modules wrapped with plastic.

Figure 2 John Deere round module harveter

This study is a more in depth version of that reported earlier (van der Sluijs and Freijah 2016, van der Sluijs, Freijah et al. 2017a, van der Sluijs, Freijah et al. 2017b) and aims to investigate the consequence of plastic contamination, under commercial conditions, on the two major spinning systems (e.g. ring spinning, both carded and combed and rotor spinning) in terms of textile processing performance and yarn and fabric quality. In order to quantify the results, this study was conducted without foreign matter detection and removal systems in the blowroom and on the winding and rotor spinning machines.

Materials and Methods

Unfortunately, despite their best intentions not all plastic is removed in the module feed area by operators or by the mechanised systems implemented to automatically remove the wraps and consequently fragments of plastic are possibly introduced into bales (van der Sluijs and Krajewski 2015). In actual fact several studies conducted by the USDA have shown that about 17% of plastics that enter the gin end up in the bale (Byler, Boykin et al. 2013, Hardin, Byler et al. 2015, Hardin and Byler 2016, Whitelock, Pelletier et al. 2018) This can lead to large financial claims and losses, which can cause irreparable harm to the relationship between growers, ginners, merchants and textile and clothing manufacturers - see Figure 3 for examples of plastic wrap caught on module feeder beaters, lint cleaner and in bale samples for classing.

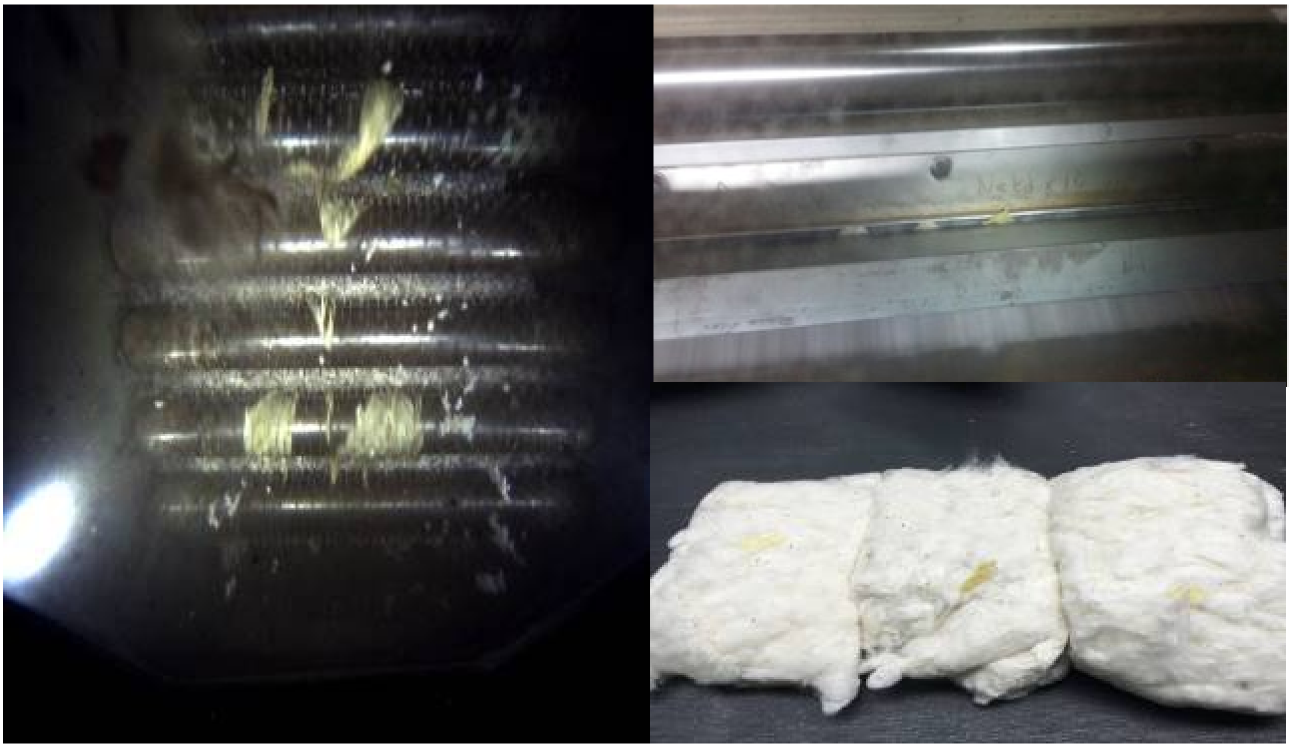

Figure 3 Image of module wrap caught on module feeder beaters, lint cleaner and bale samples for classing.

During the 2015 season two gins segregated bales suspected of being contaminated and employed additional labor to manually remove contaminants. This manual removal of contaminants turned out to be costly, time consuming, tedious and prone to human error and was hence abandoned, with the remaining bales severely discounted. Fortunately, a number of bales were decontaminated with the plastic wrap removed from each bale bagged and tagged separately to quantify the magnitude of contamination. From this it was ascertained that on average 4 to 8 grams of plastic was found in the contaminated bales. In order to conduct some further trials, two full lint bales of 227 kg were purposefully contaminated with 6 and 8 grams of the removed plastic at the battery condenser prior to bale formation- see Figure 4 for images.

Figure 4 Six and eight grams of plastic wrap used to contaminate bales

<u>Trial 1</u>

This trial was conducted to determine the amount of plastic wrap extracted during the opening, cleaning and carding process. The bale contaminated with 8 grams of plastic wrap was thus processed through an industrial size Trutzschler blowroom and carding machine under commercial conditions at CSIRO's cotton mill installed in Geelong. The bale was fed into the blowroom using a CS bale opener, followed by a Cleanomat CVT 3 cleaner, MSL material reserve hopper and a DK903 carding machine. Under normal circumstances the trash, dust and impurities removed during this process are transported by air for filtration. In this trial two Waste Box Collectors

(WAC) were connected to the various extraction points of the Cleanomat cleaner and carding machine with the waste from the CS and MSL machines transported to the coarse filter. One WAC with three compartments was attached to different parts of the carding machine. Stationary flats - C1, Revolving flats - C2 and Licker-in - C3 - see Figure 5. The other WAC with two compartments (CM-1 & CM-2) was connected to the Cleanomat CVT 3 cleaner - see Figure 6.

The waste and impurities extracted were then manually inspected, randomly to minimize any bias, by two experienced technicians with all plastic wrap found in all the WAC compartments bagged, tagged and weighed separately for each card can produced.

Figure 5 WAC connection to carding machine

Figure 6 WAC connection to Cleanomat

<u>Results</u>

Once the carding machine was setup, twenty three cans of sliver (2000 meters per can @ 4590 tex and weighing approximately 9.2 kg) were produced from the bale of cotton, with the waste and impurities extracted to produce one card can of sliver bagged, tagged and weighed separately - see Figure 7 and Table 1 for examples and details of the amount of waste and impurities extracted and plastic wrap found in the various WAC compartments per card can.

Table 1 shows that no plastic wrap was removed during the cleaning stage (CM) and that the plastic wrap was mainly removed by the carding machine with a very small amount, 0.0043 grams, removed during the opening stage and found in the coarse filter waste. In total thousands of very small pieces of plastic wrap (see Figure 8) weighing 3.3311 grams were found by the technicians and removed from the various waste streams collected by the WAC's. The majority (99.2%) of plastic wrap was removed by the revolving flats (C2), followed by 0.6% by the stationary flats (C1) and 0.1% by the licker-in (C3). This was not entirely unexpected as previous studies have shown that the vast majority of contaminants remain present and intact during the opening and cleaning stages in the blowroom, but then become fragmented later. Furthermore, although several contaminants are removed during the carding process (Ray and Chatterjee 2001, van der Sluijs, Freijah et al. 2017b), the large majority are severely fragmented during carding, mainly due to the action of the revolving flats (Walraf 2000, Faerber, Leder et al. 2010, Faerber, Leder et al. 2010, van der Sluijs and Freijah 2016).

Figure 7 Image of impurities removed per card can of 9.2 kg.

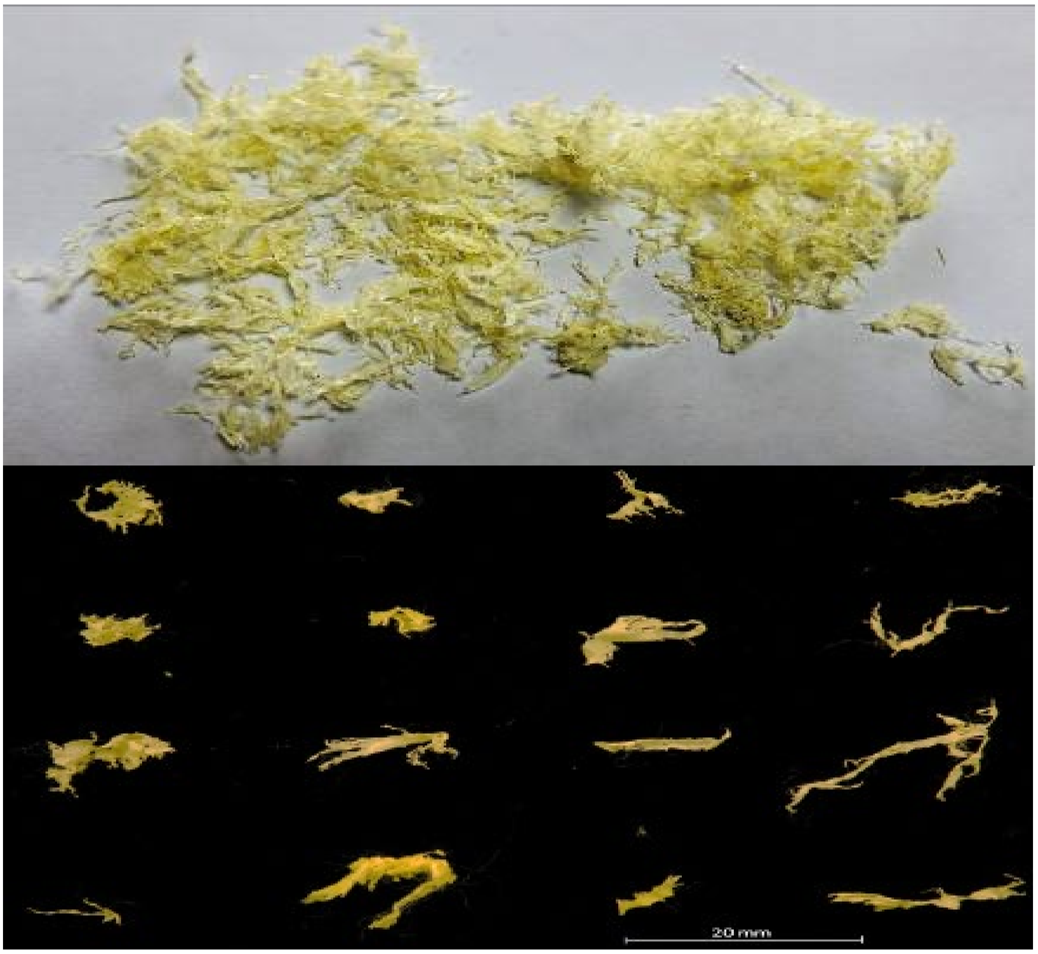

Figure 8 Examples of plastic wrap removed per card can of 9.2 kg.

Table 1 Total wieght of waste and impurities extracted and total weight of plastic wrap found per card can

Can Number	Waste collected in gram				Plastic found in gram			
	CM	C1	C2	C3	CM	C1	C2	C3
Can 1	40.2	41.5	112.0	0.3	0	0	0	0
Can 2	32.7	41.3	127.4	0.3	0	0	0	0
Can 3	40.6	40.9	112.0	0.3	0	0	0	0
Can 4	49.0	42.5	139.4	0.3	0	0	0	0
Can 5	29.7	40.9	121.5	0.3	0	0	0.0358	0
Can 6	29.0	41.4	111.8	0.2	0	0	0.0467	0
Can 7	21.7	38.2	110.7	0.1	0	0	0.1880	0
Can 8	32.0	39.9	120.2	0.1	0	0.0005	0.1767	0
Can 9	22.6	39.0	117.1	0.3	0	0.0026	0.3748	0
Can 10	14.9	38.3	115.0	0.2	0	0	0.1509	0
Can 11	12.2	38.7	113.4	0.3	0	0	0.3206	0
Can 12	17.1	41.0	126.6	0.4	0	0.0003	0.3763	0
Can 13	12.6	41.6	121.6	0.4	0	0	0.2981	0.0002
Can 14	15.3	43.1	122.5	0.3	0	0.0061	0.1861	0
Can 15	16.0	43.5	122.0	0.4	0	0.0072	0.1281	0.0016
Can 16	13.4	42.8	113.2	0.4	0	0.0001	0.2923	0
Can 17	14.7	43.5	122.9	0.4	0	0.0002	0.2950	0
Can 18	15.3	42.8	127.8	0.4	0	0	0.0660	0
Can 19	13.7	42.9	122.6	0.3	0	0.0019	0.2917	0
Can 20	16.2	40.8	116.2	0.4	0	0	0.0647	0
Can 21	14.5	41.6	122.8	0.3	0	0	0.0143	0
Can 22	20.0	44.6	130.3	0.3	0	0	0	0
Can 23	5.2	43.5	107.2	0.2	0	0	0	0
Average	**21.7**	**41.5**	**119.8**	**0.3**	**0**	**0.0008**	**0.1437**	**0.0001**
Total	**498.6**	**954.3**	**2756.2**	**6.9**	**0**	**0.0189**	**3.3061**	**0.0018**

Trial 2

The results from Trial 1 showed that ≤ 42% of the plastic wrap present in the lint bale was removed during carding, mainly due to the action of the revolving flats, which also resulted in the plastic being torn into smaller pieces and fragments. These may be difficult to remove subsequently and may remain largely undetected, only becoming noticeable in subsequent processing stages and quite late in the conversion process. This follow up trial was thus conducted to determine if plastic wrap, that was not extracted by the carding machine will survive during yarn manufacturing and detected in fabric.

The complete bale with 6 grams of plastic wrap was thus processed by the Trützschler blowroom, carding machine and HSR 1000 drawframe. The waste and impurities extracted during these processing stages were transported by air to the Trützschler SFV123 coarse and SFF2 fine filters. After these processes the sliver was then randomly split in three ways to produce 30 Ne carded and combed ring-spun yarns and 20 Ne rotor-spun yarns, suitable for producing single jersey knitted fabric.

For ring-spun combed yarns, the fiber was processed through a Vouk RD3000-E/2T lap former and CM 400/S comber, Zinser 660FU flyer and RM350 ringframe and Schlafhorst AC238RM winder equipped with MK-C20 clearers. The same processing route was followed for ring-spun carded yarns except for the Vouk combing machines. For rotor-spun yarns, the fiber was processed through a Schlafhorst SE11 spinning machine. All the yarns were then steamed and knitted into a single jersey fabric with a Falmac 2-4 SM J circular knitting machine. All the undyed greige fabric rolls were then inspected by two experienced technicians both visually and by touch on an inspection table with background lightning and meter counter. Both sides of the fabric were inspected with the location of the plastic pieces marked with the meters on the counter recorded. All the fabric rolls were subsequently scoured and dyed in a Scholl Stubtilo Pressure jet with Cibacron Blue LS3R, after which the fabric was dried with a Rousselet hydro extractor and thereafter with a Gyson dryer. All plastic pieces found were photographed using a Wild M420 photomicroscope.

Results

The waste and impurities extracted and accumulated in the coarse and fine filters was manually inspected by two technicians with all plastic wrap found removed and bagged. Once again, many thousands of very small pieces of plastic wrap weighing 3.82 grams in total were found by the technicians. This equates to 64% of the initial amount present in the bale.

Table 2 provides details on the number and the total length of fabric rolls produced by the three spinning systems as well as the total number of plastic wrap pieces found on both sides of the fabric for the greige (undyed) and dyed fabric. What is abundantly clear is that despite their best efforts, the technicians failed to detect many of the plastic wrap pieces present in the greige fabric. This was in all likelihood due to the fact that the plastic wrap pieces were extremely small, with most pieces weighing ≤0.00002 grams, and this in combination with the color of the plastic wrap layers (yellow, beige and translucent yellow) made them almost invisible to the naked eye and touch and thus very difficult to detect. For the rotor-spun fabric there was an increase of 240% (48 pieces), for combed ring-spun of 373% (41 pieces) and for the carded ring-spun 300% (21 pieces) in the number of plastic wrap pieces detected in the dyed fabric as compared to the greige fabric.

Table 2 also shows that at 45 plastic wrap pieces per 100 meters, the ring-spun combed yarn contained the most plastic wrap pieces; 53% more than the ring-spun carded fabric and 26% more than the rotor-spun fabric. The higher number of plastic wrap pieces found in the ring-spun combed fabric was in all likelihood due to the action of the circular comb and the fine needles which whilst remove trash, neps, short fibers and other impurities, including plastic wrap also fragments the plastic pieces into even smaller pieces. Similarly, during the rotor spinning process the action of the opening roller which individualizes the fibers, removes trash and impurities also leads to further fragmentation of the plastic wrap.

The amount of plastic wrap found in the knitted fabric was above the acceptable levels of contamination which should not exceed 10 fibers/100 km for ring-spun combed cotton yarns and 20 fibers/100 km for ring-spun carded yarns (Furter 2006). Although, there is a possibility of removing contaminants manually from the fabric, this is not practical as it is very time consuming, expensive and difficult for knitted fabrics, as this is likely to damage the fabric and cause holes (van der Sluijs 2009, van der Sluijs and Hunter 2018).

Figures 9 to 11 show examples of plastic wrap pieces found in the griege and dyed fabrics processed by the three spinning systems. These images show that all three components of the wrap; yellow, beige and translucent yellow were present in the fabrics.

Table 2 Details on Fabrics produced and plastic wrap pieces found in griege and dyed fabrics

Spinning system	Number of rolls	Total length (m)	Total number of plastic pieces in griege	Total number of plastic pieces in dyed	Plastic pieces per 100 m
Rotor	5	202.7	20	68	34
RF Combed	2	114.5	11	52	45
RF Carded	2	132.4	7	28	21

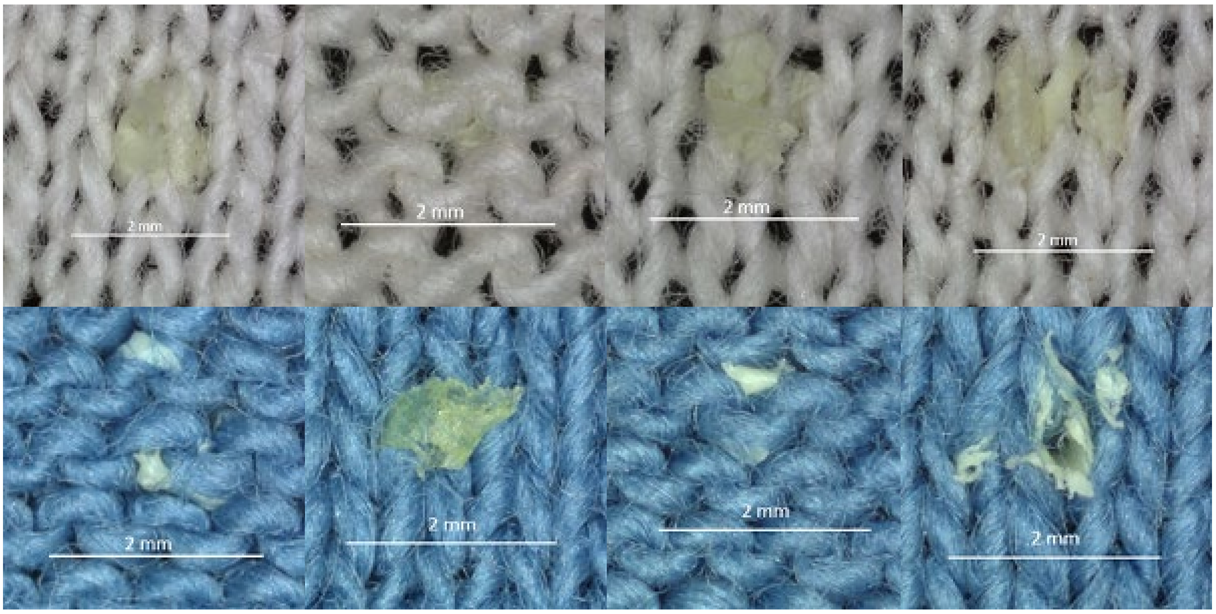

Figure 9 Examples of plastic wrap found in rotor-spun greige and dyed fabric

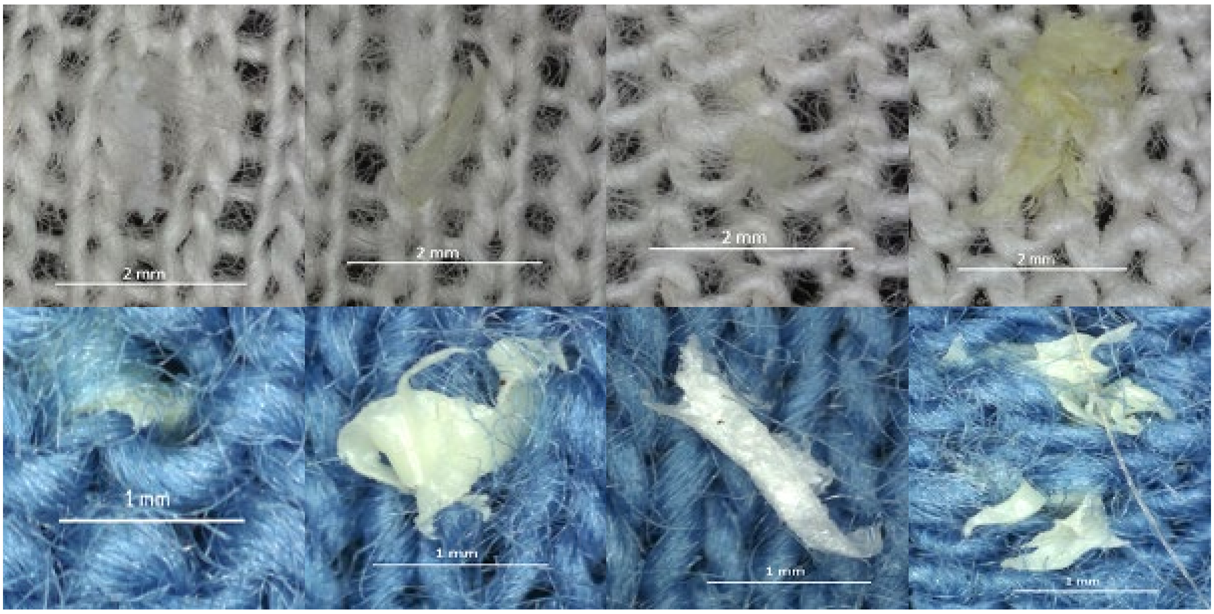

Figure 10 Examples of plastic wrap found in ring-spun carded greige and dyed fabric

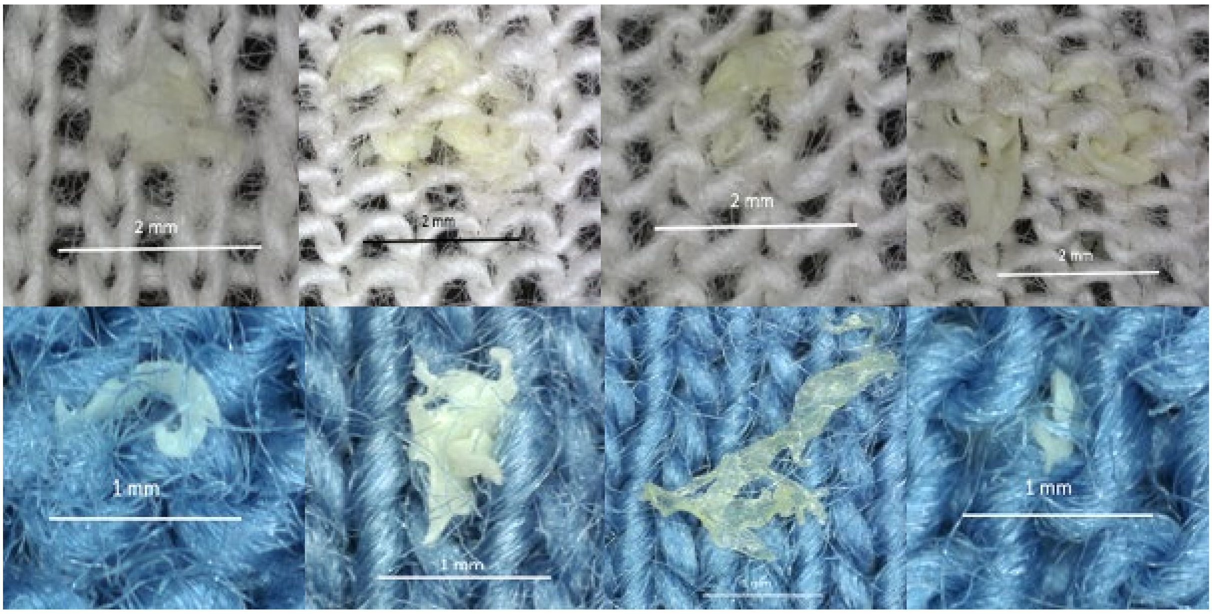

Figure 11 Examples of plastic wrap found in ring-spun combed greige and dyed fabric

Conclusion

This study has shown that plastic module wrap can have disastrous consequences if allowed to enter the ginning process as it will be fragmented into very small pieces during processing. These small pieces will only be detected in finished fabric and this can lead to large financial claims and losses (van der Sluijs and Hunter 2018). It is also clear that due to their size and color that the wrap is difficult to detect without the installation of automatic detection and removal systems at various stages of the cotton production pipeline. Unfortunately, these systems are expensive, not 100% effective with a number, especially at the ginning stage, still in the development stage (Whitelock, Byler et al. 2017, van der Sluijs and Hunter 2018, Whitelock, Pelletier et al. 2018, Holt, Pelletier et al. 2019).

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Disclaimer

Mention of any trade names or commercial products in the publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the author.

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