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THE CONTAMINATION OF WOOL BY HIGH DENSITY POLYETHYLENE (HDPE) WOOLPACK MATERIAL

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ABSTRACT

Pilot-scale processing trials were carried out with wool which had been packed in a new low fibrillating, high density polyethylene (HDPE) material developed by a South African firm. Excessive damage to the bales was created during conventional coring and grab sampling in order to accentuate differences between this material and conventional HDPE pack material in terms of their relative potential to contaminate the wool. The relative degree of removal of HDPE remnants during processing was subsequently studied by seeding scoured wool with HDPE strips on the feed lattice of the card and analysing the processing wastes.

Compared with the conventional pack, the new pack was found to contaminate the wool to a much lesser degree than the conventional pack. The low fibrillating type also appeared to be more readily removed during processing than the conventional type.

INTRODUCTION

Complaints about woolpack contamination have been part and parcel of the wool industry for many years. As far back as 1907[1], the trade press in the U K raised this matter and expressed the opinion that "missionary work in the colonies" was urgently required in order to reduce the incidence of contaminants of a vegetable nature in wool. Hawkesworth[2] also published a letter from the Wool Trade Section and the Spinners Section to the Bradford Chamber of Commerce in which the incidence of "fragments of jute, string, twine and bagging material in colonial and foreign wools" was again severely criticised. The Chamber war urgently pressed to raise this matter with all wool producers in the British colonies.

Woolpack contamination is an example of the acquired class of impurity often present in raw wool. Such contaminants, especially those of a non-protein fibrous nature, are often not easily removed during processing and show up as faults in dyed fabric as a result of their non-affinity for wool dyes. It has always been widely recognised that these contaminants enter the wool mainly via inspection slits cut in the pack and also as a result of the fraying of binding twines and threads[1, 2, 4]. Not easily removed during carding or combing, such contaminants have to be manually picked from the finished cloth during a process called burling. With current wage structures for labour, burling has understandably become virtually prohibitive in cost.

In South Africa, the problem of woolpack contamination was recognised many years ago. As early as 1924 Kruger[3] advised South African wool growers to take special care before packing shorn wools for shipment, and suggested a singeing process to remove all loose jute fibres from the inside of packs before use. However, there is very little evidence either to show that this recommendation was put into practice to a large extent, or proved to be successful as a method of avoiding contamination.

Over the ensuing years, several other approaches were also made in an attempt to solve the problem of woolpack contamination. In his textbook "The Marketing of Wool", du Plessis[4] listed several of these approaches and potential approaches. These include substitutes for jute (e.g. a woven all-wool container), the use of a loose stockinette lining in the pack, a wire-mesh pack lined with either paper of a felted wool cloth, an all-paper pack, a coir fibre pack and the use of a rubber-lined pack. However, none of these (with the exception of the paper pack) ever reached commercial exploitation on a large scale, the general consensus after various experiments and field trials usually being that the cheapest solution was to ensure the production of good quality jute packs and twine and the exercising of greater care in slitting bales for inspection in warehouses. During the late 1960's the idea of using paper was revived with the development of a 100% paper pack in South Africa[5] and later the development of a paper/nylon composite material in Australia[6]. The arguments forming the basis of these developments were mainly the ease of removal of the paper component during processing and the fact that nylon and wool are dyed with the same dyestuff types. Nylon remnants can thus be effectively hidden in the dyed fabric. However, due to high cost, poor handle and variable strength the paper pack developed in South Africa was discontinued in 1973. The paper/nylon pack is currently being evaluated in Australia.

The use of plastic materials as substitutes for jute has had by far the greatest economic success. Today the traditional jute woolpack has been replaced almost entirely by a high density polyethylene (HDPE) woolpack. The move towards using plastics (particularly polyolefins) started with research into the use of polypropylene packs in the 1960's. The results were promising and polypropylene was later superceded by HDPE. The advantages originally claimed for using plastic packs were mainly associated with their lower potential for contaminating the wool. However, there has since been evidence that the problem of fibrillation and subsequent contamination has not entirely been solved by these developments, the fibrillar contaminant apparently again not being removed during processing and subsequently appearing in the dyed article as a light (undyed) fibre[7].

The actual mechanism by which HDPE pack material fibrillates and the subsequent introduction of such fibrills or any other form of plastic contamination into the wool were recently investigated by Foulds and James[8], who found loose bale caps to be a major source of contamination. In addition, the fibrillation process is also still induced largely by bale slitting procedures, which today involves the use of hydraulically driven grab jaws to break the pack material for the extraction of grab samples for display.

A South African firm has recently developed what they term a "low fibrillating" HDPE pack which, it is claimed, will largely eliminate fibrillation and thus obviate plastic contamination of the combed top. The pack is woven from a product based upon co-polymerisation of ethylene with certain other monomers to improve the physical structure of the composite polymer product, which; in turn, has been claimed to reduce the tendency of the material to fibrillate. The new product is extruded from the polymer melt into tapes of the required width and thickness, as opposed to the conventional HDPE tapes which are slit from polymer sheets. This paper describes pilot scale processing experiments with wools packed in this new material to assess its merits relative to conventional HDPE, particularly from a contamination point of view.

MATERIALS AND METHODS

Wool

An inferior topmaking style wool of 21 μm mean fibre diameter and 82 mm staple length, with low VM content (1,4%), was divided into four replicate 140 kg processing batches. One batch was packed into an unused standard HDPE woolpack and the other into a prototype low fibrillating HDPE woolpack. The remaining two batches were retained unpacked.

Analysis of the Pack Material

The Technical Services Department of the S.A. Wool Board is responsible for the quality control of all woolpacks used in South Africa. The packs used in this project were tested against the relevant requirements for woven plastic woolpacks[9] at the Board's laboratory. In addition, the tensile strength and elongation properties of individual tapes drawn from both warp and weft directions were tested at SAWTRI using an Instron tester[10]. After this test, the ruptured ends of some of the tapes were examined and photographed for a subjective assessment of the relative degree of fibrillation of the two types of material. The linear density of the tapes was estimated by drawing a number of one metre lengths from both warp and weft directions and determining their mass individually.

Induced Contamination

For the purpose of this project, it was assumed that certain procedures in the warehouse prior to shipment can be a major source of contamination. In the first of two experiments, the pre-packed wool bales were subjected to a grab and core sampling routine using standard commercial equipment in the broker's store. To induce a maximum degree of contamination, the requirements laid down by the S.A. Wool Board's sampling protocol were deliberately violated to create a "worst case" situation. Each bale was subjected to a simulated grab sampling cycle by forcing the closed jaws of the sampling head into the bale in a 3 x 3 grid pattern on one side. The bale was then rotated through 180° and the cycle repeated. Subsequently, the bale was turned upright and a core sampling tube inserted in a random pattern over the full surface area of the bale face. Approximately fifteen entries were effected. Fig. 1 shows the extensive damage to the two bales caused by this operating sequence.

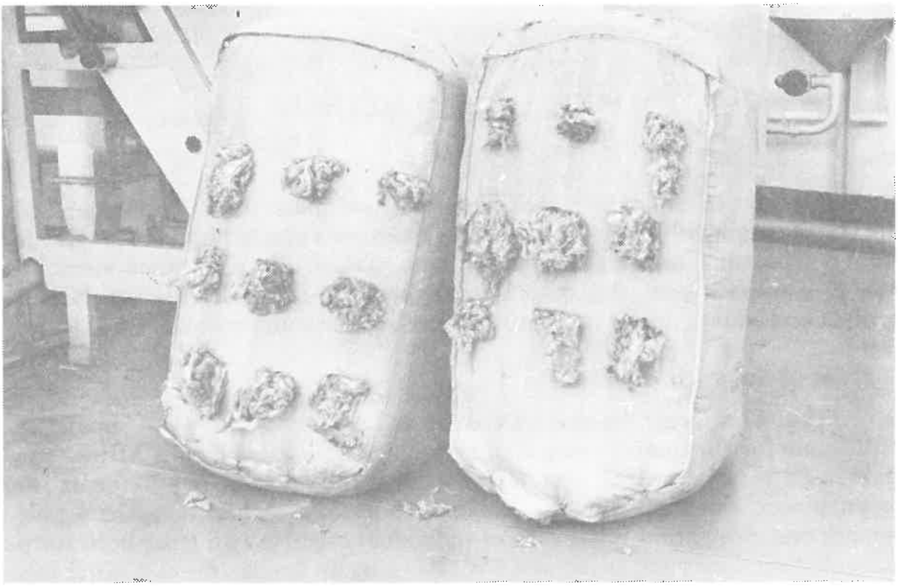

Fig. 1 – Damage induced by excessive number of grab jaw and core tube penetrations.

In the second of the two experiments, contamination was artificially induced prior to the carding process to assess to what extent HDPE contaminants were removed at the various stages of topmaking. For this purpose pack material (the standard type as well as the low fibrillating type) was cut into strips of 10 mm x 40 mm and subsequently seeded into the scoured wool on its transit from underneath the hopper weighpan to the feed rollers on the breastworks of the card. The concentration of the contaminants was 1% on mass of scoured wool.

Processing and Testing of the Contaminated Wool

The four processing batches from the two experiments described above were converted into top by means of the usual SAWTRI routine which involves pilot scale scouring, double swift continental worsted carding and combing on a Schlumberger PB26L rectilinear comb.

Samples of the card sliver and the top sliver were obtained during and after the processing of each batch and tested for the incidence of plastic contaminants by visual assessment using a Toennissen top tester. Some of the tops were also dyed to an 8% depth of shade with a chrome dye (®Eriochrome Black T) to facilitate this assessment.

In the case of the second experiment, the various waste products generated by carding and combing were also collected after processing and analysed for their concentration of HDPE remnants. Three sites were used for collection of the wastes, namely at the burr removal zone on the card, underneath the card and from the noil box on the comb. The collected wastes were thoroughly mixed on an individual basis and then sub-sampled by means of a "mini-coring" technique. The subsequent analysis of the HDPE concentration in the core samples of these wastes was based on selective dissolution of the two main components in the waste, namely wool and polyethylene. Firstly, the wool component was dissolved by treatment with a sodium hypochlorite/sodium hydroxide mixture. The residue containing vegetable matter and HDPE remnants was then rinsed and then treated with boiling xylene to dissolve the polyethylene component. The composition of the wastes was then calculated according to the mass loss data obtained after weighing the starting material and the various residues obtained.

RESULTS AND DISCUSSION

Pack Material Test Results

The estimated linear densities of the individual tapes drawn from the pack specimens were 201 tex (CV = 16%) for the conventional type and 191 tex (CV = 11%) for the new type. To obtain the required sett and mass per unit area specified for woolpacks[9], limits of 182 ± 10% have been claimed to be acceptable for production purposes[11].

For information, typical strength and extension characteristics of the pack material, as determined by the strip method[12], are given in Table 1 together with the minimum requirements listed in the appropriate SAWB specification[9].

TABLE 1

MASS, TENSILE AND ELONGATION PROPERTIES (STRIP TEST)

Property	Weave Direction	Specification Requirements[9]	Test Results	
			Standard Pack	New Pack
Mass ($g.m^{-2}$)	—	240	244	248
Breaking Strength (N)	Warp Weft	1850 (min) 1700 (min)	2068 1887	2164 1816
Extension at Break (%)	Warp Weft	35 (max) 20 (max)	18,5 15,2	21,3 16,7

It can be seen that the new pack specimen was well above the minimum requirements for breaking strength and below the maximum extension requirements, the new pack material appearing to be slightly more extensible compared with the standard pack. Both packs were woven slightly denser than the requirements.

Based on test results for single tapes drawn from undamaged portions of the packs used in this study, the results showed that the elongation properties of the single tapes also differed slightly, depending on weave direction. This is illustrated by the data in Table 2, which shows the average values for 15 individual strand tests. Fig. 2 illustrates typical stress/strain curves for single tapes comprising the two types of material.

TABLE 2

TENSILE AND ELONGATION PROPERTIES (SINGLE TAPE TEST)

PROPERTY	STANDARD PACK		NEW PACK	
	Warp	Weft	Warp	Weft
Breaking Strength (N)	63,3	62,6	70,8	72,1
Breaking Extension (%)	14,4	12,0	21,5	15,0

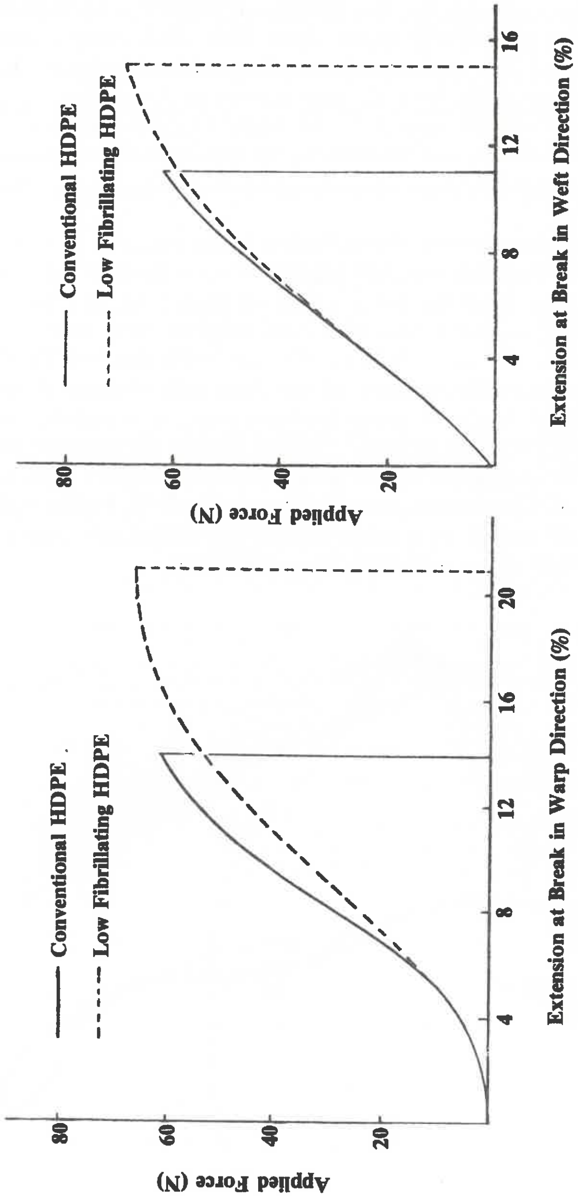

Fig. 2 – Typical stress/strain curves for HDPE pack material tapes.

It can be seen that although the low fibrillating HDPE tapes tended to be stronger than the standard HDPE tapes, they were also more extensible. Therefore, when the closed jaws of the grab sampling machine is forced through the fabric during sampling of the bale, the penetration of the stretched packing material into the wool bulk contained in the pack could be expected to be slightly higher in the case of the low fibrillating HDPE material. The strip test data (Table 1) and the stress strain curves illustrated in Fig. 2 also serve to support this conclusion.

As far as the relative degree of fibrillation upon rupture of a strand is concerned, Figs 3 and 4 illustrate the differences between strands from the standard pack (Fig. 3) and from the low fibrillating pack (Fig. 4). The strands obtained from the standard pack tended to disintegrate into relatively fine fibrils, while this appears not to have been the case with the low fibrillating material. However, further examination of the ruptured strands of the low fibrillating tape at higher levels of magnification using a scanning electron microscope revealed the presence of some fibrillar debris on the tape surface. This debris appeared to constitute a fine, short fibrous material which could possibly be evidence of fibrillation on a micro-scale. It is highly unlikely, however, that this would constitute a contamination problem as it appeared to be virtually invisible without considerable magnification.

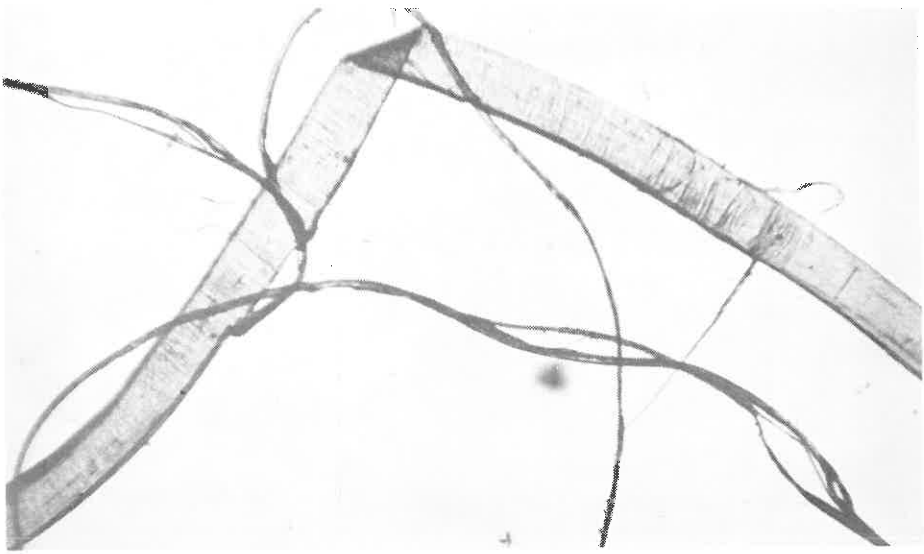

Fig. 3 – Fibrillation of standard HDPE tapes during rupture on the Instron (Magnification 32 ×)

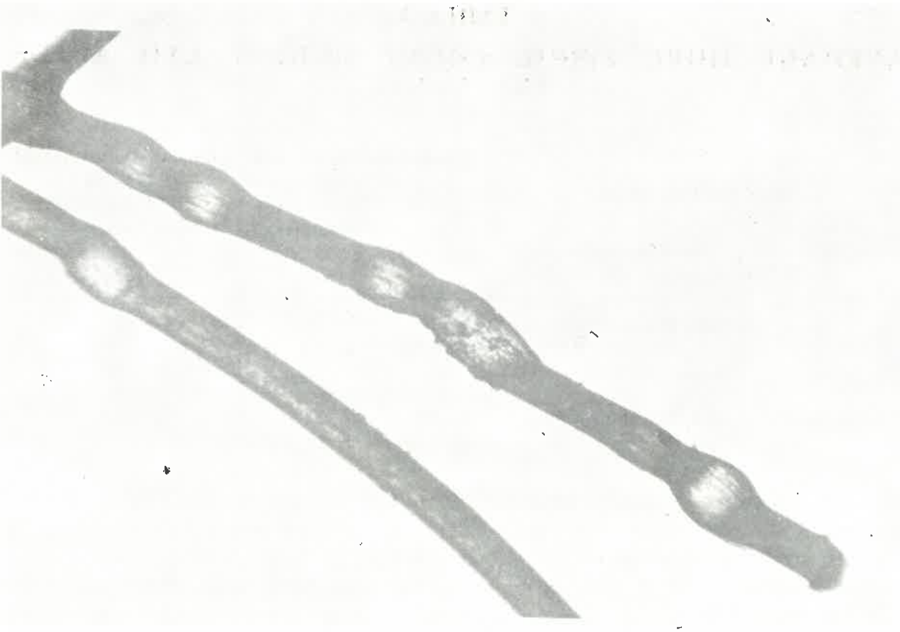

Fig. 4 – Split tape remnants of low fibrillating pack material after rupture on the Instron (Magnification 32 ×).

Processing Analysis

The results for tests on the carded sliver and the combed sliver for residual HDPE are given in Table 3 for both series of experiments.

The fibril counts for the wools processed after the grab sampling and coring sequence were considerably lower than those of the wool artificially contaminated by seeding. For example, in the case of the card slivers, the mean values suggested a lower degree of contamination with the low fibrillating pack, although the between-sample variation was found to be relatively high. After combing there also appeared to be fairly conclusive evidence ($P < 0{,}05$)that the residual HDPE contaminants in the case of the low fibrillating material was lower than in the case of wools packed in the standard pack material. In fact, no low fibrillating HDPE remnant could be detected in the top even after testing a large number of individual sliver lengths (i.e. repeated testing of different samples in excess of statistical requirements). These results, therefore, suggest that the observed effects could have been associated with the ease of removal of

TABLE 3

AVERAGE HDPE FIBRIL COUNT DURING AND AFTER PROCESSING

PROCESSING STAGE		Contamination through Grab Sampling and Coring (HDPE Fibrils per kg of Sample)	Contamination Induced by Seeding (HDPE Fibrils per kg of Sample)
After Carding	Standard Woolpack	39	1670
	Low Fibrillating Pack	19	1122
After Combing	Standard Woolpack	17	1294
	Low Fibrillating Pack	0	650

the low fribrillating HDPE remnants from the scoured wool. (This led to the design of the second experiment in which the scoured wools were seeded with HDPE strips in order to investigate this aspect in more detail.)

In the case of the artificially induced contamination, differences after the carding stage were again evident. The evidence was conclusive that the standard woolpack was associated with twice as much HDPE remnants in the top than the low fibrillating pack. In both cases one may therefore conclude that although the low fibrillating HDPE tape did tend to split upon rupture (see Fig. 4) these remnants were sufficiently large to be easily removed during processing, while in the case of the standard woolpack (see Fig. 3), the remnants were of a more fibrous nature, not as easily removable and hence more likely to persist through processing into the top. In general, therefore, the results in Table 3 suggest that coring and grab sampling wools packed in the low fibrillating HDPE would appear to have a considerably smaller chance of being the cause of contaminated tops than would be the case with wools packed in the standard HDPE packs.

It was also thought to be of interest to check the various waste products generated by processing for their relative degree of contamination with woolpack material. The results are given in Table 4 for the experiment involving deliberate contamination by seeding.

The results show that by far the largest proportion of the pack material strips entering the card was ejected by the burr roller. Of the remaining HDPE which is removed the larger proportion dropped out underneath the card and formed part of the sweepings, while a relatively smaller amount (0,2% to 0,3%) was found in the card strippings. The comb removed just under 3% of the input contamination. A considerable portion, in fact, of the contaminants apparently

TABLE 4

CONCENTRATION OF HDPE IN WASTE PRODUCTS (% BY MASS)

WASTE PRODUCT	STANDARD WOOLPACK			LOW FIBRILLATING PACK		
	Waste Product as a percentage	Percentage of waste comprising HDPE	HDPE in in waste as percentage of input contamination	Waste Product as a percen tage	Percentage of waste comprising HDPE	HDPE in waste as percentage of input contamination
Burry Waste	2,8	8,9	24,5	2,8	14,6	41,3
Card Strippings	1,2	0,2	0,3	1,2	0,43	0,2
Fly and Sweepings	8,5	1,9	15,8	9,2	1,5	13,8
Comb Noil	16,6	0,2	2,8	16,8	0,2	2,9
TOTAL	—	—	43,4	—	—	58,2

entered the top, presumably either as a result of further strip material breakdown at the feed rollers which gave rise to smaller pieces which escaped ejection into the burr can, or possible further fibrillation which was not removed by the comb, or both. The important feature to note from Table 4, however, was the large difference between the two types of pack material. Considerably more low fibrillating HDPE was removed by the burr beater than was the case with standard HDPE. The comb did not appear to differentiate between the two types of material to any appreciable degree. Nevertheless, the overall removal rate for the low fibrillating type was some 35% better, on a mass basis, than for standard type, which suggests that should contamination inadvertantly occur, the low fibrillating type would appear to have a better chance of being removed during carding and combing. This confirms to a certain extent the conclusions based on the visual counts of residual contamination in the tops given in Table 3.

SUMMARY AND CONCLUSIONS

Processing trials with wools packed in either standard high density polyethylene (HDPE) or in a newly-developed low fibrillating HDPE were carried out to assess the relative propensity of these two products for contaminating the top with residual HDPE. Prior to scouring, carding and combing, one bale in each case was subjected to a conventional grab sampling and core testing routine in such a way so as to create aritificially high levels of contamination. Contamination was also induced artificially during processing when a second replicate batch in each case was carded and combed after having seeded the scoured wool on the feed lattice of the card with 10 x 40 mm strips of pack material to a level of 1,0% on mass of scoureds. The degree of contamination at different stages of processing was assessed both visually by means of a Toennissen top tester and by selective chemical dissolution of firstly the wool component and secondly the HDPE component in the appropriate waste products of processing. The tensile properties of the pack material were tested using the appropriate SABS test methods, while their fibrillating propensity was subjectively assessed by photographing the ruptured ends of individual strands after the tensile test.

It was found that the newly developed low fibrillating pack material was stronger and more extensible than the conventional or standard pack material. The latter also tended to fibrillate into fine, fibre-like remnants upon rupture, while the low fibrillating type appeared to break down into relatively large strip-like remnants which were apparently more easily removed during processing. The processing trials showed that after the grab-sampling and coring experiment, virtually no residual HDPE was found in the top in the case of the low fibrillating type. Should contamination occur, however, the results of the second experiment, which comprised seeding the scoured wool with artificially high levels of HDPE material, suggested that the low fibrillating type was more readily removed during processing.

Based on the available evidence, the use of a low fibrillating pack material such as the type used in the experiments discussed here appears to have some advantage from the point of view of reduced levels of residual HDPE in combed tops.

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THE USE OF PROPRIETARY PRODUCTS

The names of proprietary products where they appear in this report are mentioned for information only. This does not imply that SAWTRI recommends them to the exclusion of other similar products.

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