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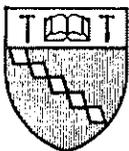
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**U A S T**

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ENGLAND

## EFFECTS OF *PENICILLIUM JANTHINELLUM* ON PARACHUTE NYLON — IS THERE MICROBIAL DETERIORATION?

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**Summary.** The role *Penicillium janthinellum* plays in the pink staining of parachute nylon and the broader question of general microbial susceptibility of nylon are reviewed. This study confirms the earlier observation that *P. janthinellum* can readily stain parachute nylon when grown on a complete medium containing a carbon source other than the nylon polymer. Mineral salts agar with and without yeast extract using parachute nylon as the sole source of carbon failed to support the growth of *P. janthinellum*. Finishing oils and other non-fibrous components removed from the nylon by solvent extraction will, however, support the growth of this organism. No statistically significant losses in tensile or tear strength of the nylon fabric were observed after extended periods of growth of *P. janthinellum* on the complete medium. Consideration is given to the significance of microorganisms and the role they may play in the degradation of nylon.

**L'action de *Penicillium janthinellum* sur le nylon utilisé en fabriquant des parachutes—Est-ce qu'il y a de la détérioration microbienne?** On discute le rôle joué par la *Penicillium janthinellum* dans les taches roses trouvées sur le nylon utilisé en fabriquant des parachutes, et aussi la question plus étendue de la susceptibilité microbienne de nylon en général. Cette étude confirme l'observation précédente que la *P. janthinellum* peut tacher facilement ce nylon quand elle est cultivée sur un milieu complet qui contient une source carbonée autre que la polymère du nylon. Le sel minérale d'agar, sans et avec extrait de levure, et employant ce nylon comme source unique de la carbone, ne pouvait pas soutenir l'accroissement de la *P. janthinellum*. Des huiles de finissage et des autres composants non-fibreux, ôtés du nylon par extraction dissolvante, peuvent, cependant, soutenir l'accroissement de cet organisme. Après des périodes prolongées d'accroissement de la *P. janthinellum* sur un milieu complet, il n'y avait pas de perte significative de résistance ni à la traction, ni au déchirement du tissu du nylon. On considère l'importance des micro-organismes, et le rôle qu'ils jouent dans la dégradation de nylon.

### Introduction

Nylon parachute materials are subject to strength losses and other changes in performance properties because of age, environment, contaminants, and use. However, nylon, like many of the pure synthetic polymers, has been assumed to have high resistance to destruction and strength losses due to microbial attack. Some claimed exceptions to this general rule have been reported recently in the literature. Dayal *et al* (1962) and Nigam (1965) at the Defence Research Laboratories (Stores), Kanpur, India, reported that *Penicillium janthinellum* No. 849 caused pink staining and a 14% loss in the tensile strength of nylon 66 parachute fabric after 42 days' exposure on potato dextrose agar (PDA) at 30°C. As a result of these findings, the Indian workers introduced a tentative method (using *P. janthinellum*) to test the resistance of different types of Service stores made from synthetic

**Effekten des *Penicillium janthinellum* an Fallschirm Nylon - Gibt es mikrobiischen Verschlechterung?** Die Rolle die *Penicillium janthinellum* in der rosa Fleckenbildung Fallschirm-Nylons spielt und die breitere Frage allgemeinen mikrobiischen Empfänglichkeit Nylons werden überblickt. Diese Untersuchung konfirmiert die frühere Beobachtungen daß *P. janthinellum* einfach Fallschirm-Nylon befleckt wenn es gewachsen wird auf einem vollständigen Medium das eine andere Quelle Kohlenstoffs als Nylon-Polymer enthält. Mineralische Sätze einhaltende Agar mit oder ohne Hefe-extrakt und mit Fallschirm-Nylon als einzigste Quelle Kohlenstoffs hat nicht den Wuchs *P. janthinellum* gestützt. Anstrichschmierstoffe und andere nichtfaserige Komponenten, abgesetzt von Nylon beim Lösungsauslaugung werden den Wuchs des Organisms stützen. Minderungen der Einreiß und Biegungsfestigkeit des Nylon Bespannstoffs, beobachtet nach ausgebreiteten Perioden *P. janthinellum* Wuchs auf vollständigem Mediums war statistisch nicht signifikant. Man zieht in Betracht die Wichtigkeit der mikro-organismus, und die Rolle, die sie in der Verschlechterung der Nylons spielen könnten.

**Los efectos del *Penicillium janthinellum* en el nilón de los paracaídas. ¿Hay deterioración microbica?** Se pasa revista al papel desempenado por el *Penicillium janthinellum* en tener color de rosa el nilón de los paracaídas y la cuestión más extensa de la susceptibilidad general microbica del nilón. Este estudio confirma la observación anterior que *P. janthinellum* puede facilmente tener el nilón de los paracaídas cuando se cultiva en un medio completo que contenga una fuente de carbón otra que el nilón polymer. Un agar de sales minerales con o sin un extracto de levadura empleando el nilón de paracaídas como unica fuente del carbón no logró mantener el crecimiento del *P. janthinellum*. Los aceites de ultima mano y otros componentes no fibrosos sacados del nilón por extracción solvente, sin embargo, pueden mantener el crecimiento de este organismo. Después de extensos periodos del crecimiento de *P. janthinellum* en el medio completo no se observó ninguna pérdida estadisticamente significante de la resistencia de tensión ni de la de rasgar. Se considera el significado de los microorganismos y el papel que puedan desempenar en la degradación del nilón.

fibers and also the preservative treatments designed to protect these materials against microbial attack.

Demmer (1968) found that fungal growth occurred on sheets of polyamide 6 and 6.6 only when a complete nutrient medium was used. When the polyamide sheets were offered to the test fungi as the sole source of carbon on a mineral salts agar, there was no fungal growth. Demmer reconfirmed previous findings that the prepolymer (caprolactam and adipic acid — hexamethylene diamine) cannot be used by the test fungi as a source of carbon. Demmer also showed, by the use of stereoscan photographs, that *Nigraspora sphaerica* caused hole-like erosion of the polyamide 6 and 6.6 sheets; this was not previously reported. No physical test data were reported to show correlation of erosion with changes in the physical properties of the sheets. Allakhverdiev *et al* (1968) reported that *Penicillium janthinellum* Biourge, *Penicillium* sp. and

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*Aspergillus* sp. caused considerable change in the color and strength of a polyamide film identified as PK-4, but no surface damage to the film was observed. This observation was made for film strips immersed in a liquid medium; the composition of the medium was not given.

In the light of these reports and because of the importance and application of nylon fabrics in military items, the present study was undertaken to reappraise the role *P. janthinellum* may play in the biodegradation of nylon and also to review the broader question of general microbial susceptibility of nylon.

#### Selection and Nylon Degrading Ability of Test Culture

Three cultures of *P. janthinellum*, QM 8464 (originally isolated from JP-4 fuel/water bottom), QM 6865 (isolated from Nicaraguan soil), and QM 8791 (same as No. 849 used by Dayal *et al* (1962)), all of which showed good pink staining on Czapek Dox and PDA agars, were used to select the strain which had the best staining capacity. Cultures were grown on PDA and, after a good spore crop was produced, the spores were washed off with the aid of an 0.1% aqueous solution of Triton X-100, and used as the source of inoculum.

Test strips of 1.1 oz. rip-stop nylon 66 (conforming to MIL-C-7020, 1965) were used in all tests. Ten replicates each of 1½" × 6" specimens raveled to 1" were prepared for all tensile measurements and 2½" × 4" specimens for tear strength tests, in accordance with Federal Test Method Standard No. 191 (1968). All test specimens were ethylene oxide sterilized by subjecting them to three 48-minute room temperature cycles. Specimens were held for 24 hours or longer at room temperature prior to inoculation. Sterilized samples were aseptically placed in 20" × 12" stainless steel trays containing Czapek Dox agar inoculated with the spores of the appropriate strain of *P. janthinellum*. The inoculated trays were inserted into sterile polyethylene bags to prevent evaporation and minimize contamination, and then incubated at 30°C for 84 days. The extent of microbiological degradation of nylon strips was measured by the change in tensile and tear strength measurements using an Instron Tensile Tester and an Elmendorf Tear Test Machine according to Federal Test Method Standard No. 191 (1968).

After 42 days' incubation, several test specimens were removed for observation. All 3 strains of *P. janthinellum* produced an abundance of pink to brownish-pink pigment in the agar. Stains QM 6865 and QM 8791 failed to stain the nylon test strips as heavily as did QM 8464. Figs. 1 and 2 clearly show

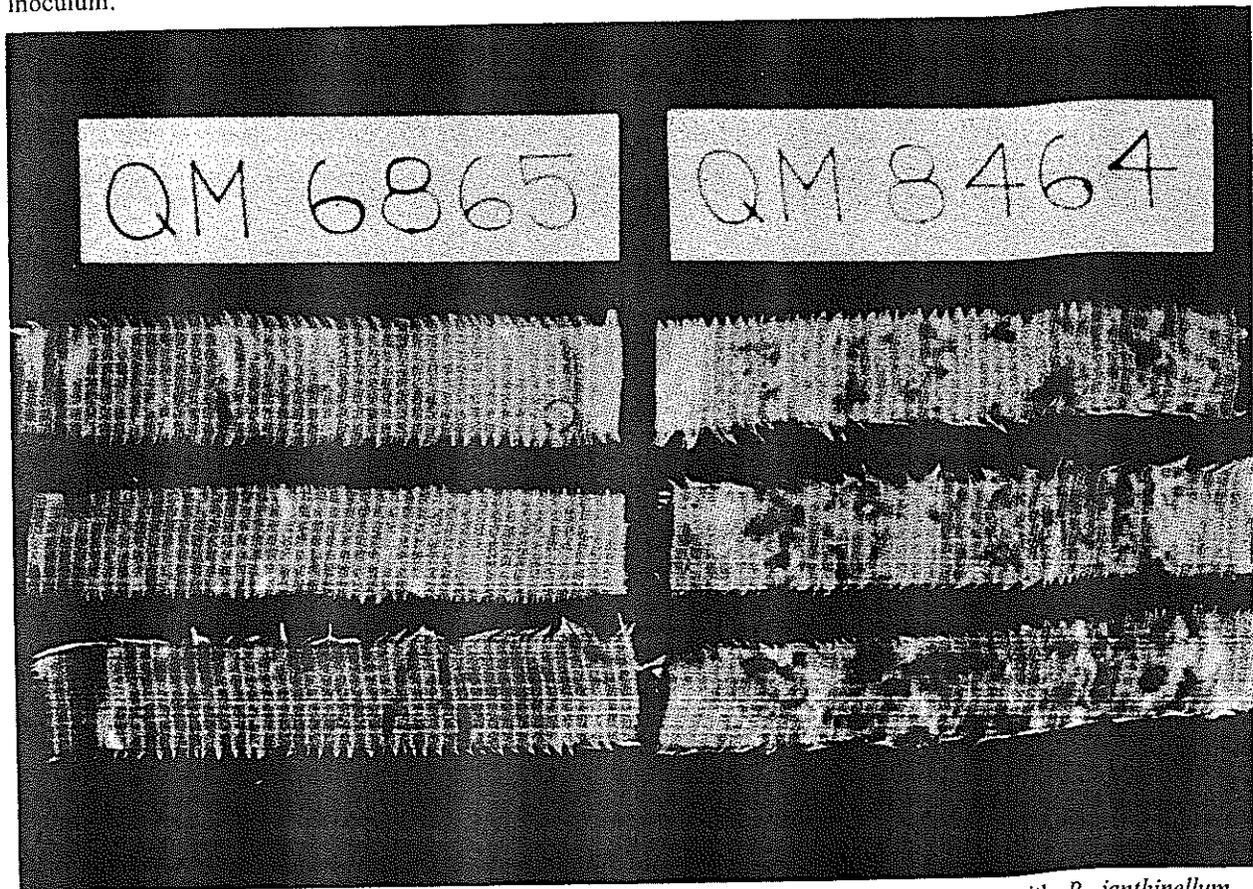


Fig. 1. Pink staining of nylon by *P. janthinellum*. Strips on left grown in contact with *P. janthinellum* QM 6865 show very little staining while strips on right were heavily stained with pink spots after 42 days' contact with *P. janthinellum* QM 8464 on Czapek Dox agar.

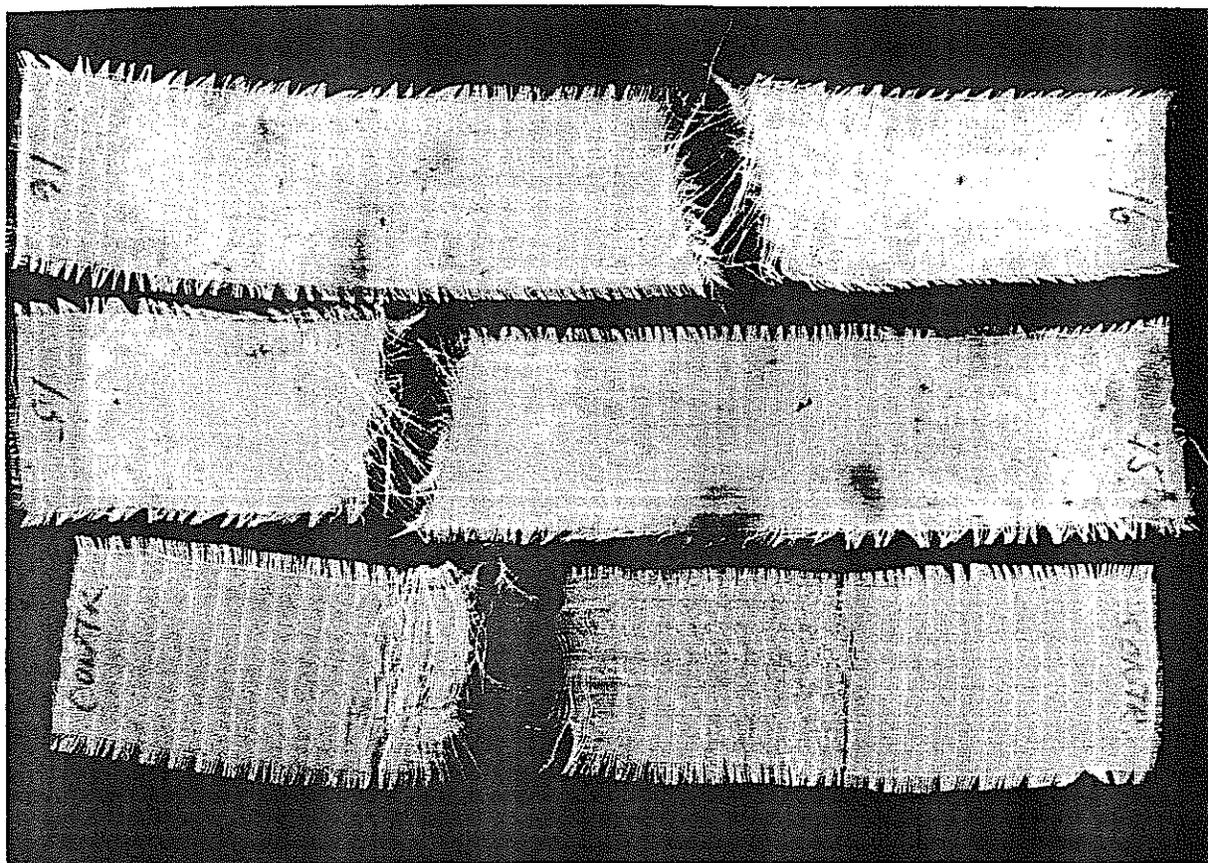


Fig. 2. Pink staining of 1.1 oz. nylon caused by *Penicillium janthinellum*, QM 8791 after 42 days' incubation on Czapek Dox agar. Bottom control strip shows appearance of nylon prior to test.

the superior staining obtained with QM 8464. The remaining test strips were then allowed to incubate for an additional 42 days, in an effort to permit heavier staining by the two lighter-staining strains. At the conclusion of the second 42-day incubation period, no significant increase in the pink staining of the nylon was observed in any of the strains.

Tensile and tear strength data are reported in Table I with the supporting statistical analysis of variance data shown in Table II (carried out according to Lindquist, 1956). These data show that none of the three strains of *P. janthinellum* effect any degradation of the nylon as measured by the physical parameters of tensile or tear strength. Although an F ratio of 4.84 (Table II) shows significance with 0.05 risk for tear strength in the warp direction, a calculated D (Snedecor, 1957) value of 0.8259 shows that there are no significant differences between the three warp-tear strength mean values after exposure to *P. janthinellum* and the control warp-tear mean value of 6.11.

The results of these initial tests showed that the deterioration observed falls into the second category of the two generally observed types of microbiological deterioration of textiles and plastics. In the first type,

the physical properties of the fabric or plastic are gradually changed through the direct or indirect attack of the microorganism on the material. In the second type of attack, the microorganisms are able to feed upon the materials with which the fibers are coated or with which the fibers or material come in contact, and thus give rise to stains and surface growth which cannot be completely removed from the fiber by washing or solvent extraction. The latter type of deterioration is usually ranked as an esthetic impairment with little or no loss in the physical properties of the material.

#### Pink Staining of Solvent Extracted Nylon

"Nonfibrous materials" used on finished nylon manufactured in accordance with MIL-C-7020 may include residual sizing, 0.3 to 0.5 per cent silicone oil, and other chloroform-soluble materials not to exceed 2 per cent of the finished nylon cloth. To test the theory that the nonfibrous components of the finished nylon cloth might influence the degree of pink staining observed and to confirm the observations of Lavrakas and Katz (1955) who showed that lubricants used on parachute nylon lines can support fungal growth, the following test procedure was used.

TABLE I.—Comparative resistance of 1.1 oz. nylon to deterioration by QM cultures of *P. janthinellum* as measured by tear and tensile strength after 84 days' incubation at 30°C.

O TIME CONTROLS - LBS			Unino- TENSILE - LBS				Unino- FILL - LBS				Unino- WARP - LBS				
Ten- sile	Tear Fill	Warp	con- trolled	QM 6865	QM 8464	QM 8791	con- trolled	QM 6865	QM 8464	QM 8791	con- trolled	QM 6865	QM 8464	QM 8791	
49.5	5.28	6.17	53.5	50.0	53.0	48.5	7.16	5.29	6.38	5.62	7.05	7.27	5.95	6.94	
57.0	6.16	6.16	48.5	53.5	49.0	44.5	5.84	5.40	6.38	5.29	5.73	6.61	4.40	6.28	
57.0	5.51	5.40	55.5	49.5	50.0	51.0	6.17	6.17	5.28	6.39	6.94	7.27	4.18	5.95	
53.0	6.16	5.95	53.0	49.5	49.5	51.0	6.83	4.29	7.04	6.50	6.61	6.17	7.04	5.29	
52.0	7.27	5.73	45.0	48.5	50.5	51.5	5.62	5.40	6.60	5.29	6.17	5.62	6.38	5.84	
53.0	5.51	6.60	50.0	49.0	52.0	52.5	6.83	5.18	6.60	5.40	6.61	7.27	6.60	5.51	
48.5	6.61	6.30	50.0	51.5	47.0	44.5	6.39	5.40	6.16	4.95	6.71	7.27	5.39	6.39	
52.0	5.61	5.70	48.5	49.5	48.5	50.5	5.29	5.29	4.29	5.95	6.17	7.05	5.28	6.83	
51.0	5.95	5.70	48.0	50.0	50.5	43.5	5.29	4.73	5.61	6.94	6.71	7.16	6.93	5.84	
50.8	6.16	7.40	50.0	53.0	49.0	50.5	4.95	5.62	5.72	5.62	5.84	7.05	6.60	6.50	
Ave.	52.38	6.02	6.11	50.20	50.40	49.90	48.80	6.04	5.27	6.01	5.79	6.45	6.87	5.88	6.14

The oils were removed from 1.1 oz. rip-stop nylon by extraction with chloroform or perchloroethylene for 2 hours in a Soxhlet apparatus. A third set of samples was double extracted; first in chloroform for 2 hours, followed by 2 hours in perchloroethylene. The 1¼" × 6" or 2½" × 4" test specimens were sterilized with ethylene oxide after solvent extraction, placed on Czapek Dox agar, inoculated with *P. janthinellum* QM 8464 and incubated as previously described.

After 84 days' incubation, all solvent-extracted samples still showed large blotches of pink staining (Fig. 3) in contrast to the numerous rather small pink spots noted (Fig. 1) with the unextracted samples. This observation would indicate that either oils play little or no role in the pink staining of parachute nylon or that the organism, growing on a full nutrient medium, did not depend on the oils for pigment elaboration.

TABLE II.—Analysis of variance for 1.1 oz. nylon exposed to three strains of *P. janthinellum*

Source of variation	df	TENSILE STRENGTH				WARP				TEAR RESISTANCE				
		Sum of squares	Mean square	F	Prob. of F	Sum of squares	Mean square	F	Prob. of F	Sum of squares	Mean square	F	Prob. of F	
Treatment	2	13.400	6.700	1.172	N.S.	5.365	2.682	a	4.84	7.05	2.814	1.407	3.258	N.S.
Error	27	154.400	5.719			14.980	0.554				11.660	0.432		
Total	29													

a = 0.8259  
N.S. = Not significant

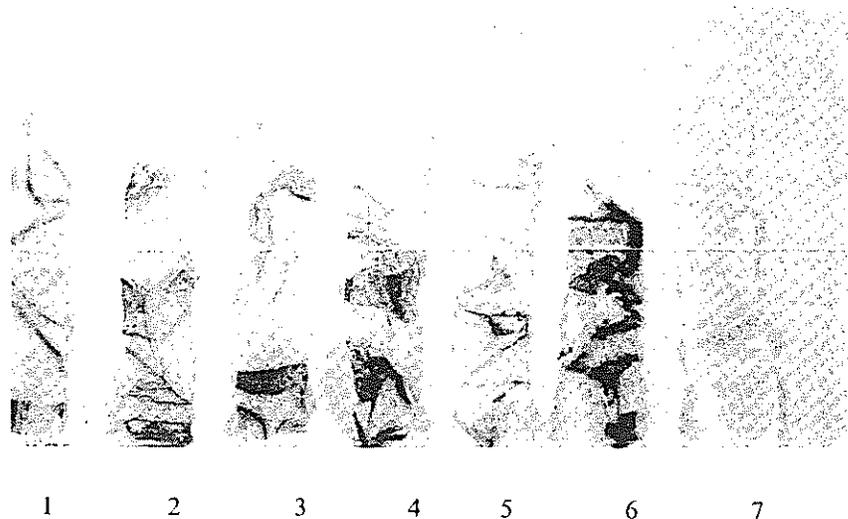


Fig. 3. Pink staining of 1.1 oz. nylon by *P. janthinellum* QM 8469 after solvent extraction and 84 days' incubation. From left to right: (1) Unextracted and unexposed control, (2) virgin nylon without solvent extraction, (3) virgin nylon extracted with chloroform and perchloroethylene, (4) parachute nylon extracted with methanol, (5) parachute nylon extracted with sodium hydroxide, (6) parachute nylon extracted with chloroform and perchloroethylene, and (7) parachute nylon extracted with chloroform, perchloroethylene, and sodium hydroxide.

#### Physical Properties and Statistical Evaluation of Solvent Extracted Nylon

The possible effects of microbial activity on the physical properties of the solvent-extracted nylon were also determined.

Tables III-VIII include the analysis of variance and the mean ratings for the tensile and tear strength of the solvent-extracted samples versus the unextracted controls. Tables III and IV show that significant

differences were found, although not large, in the tensile strength of the inoculated and solvent-extracted samples, while the interaction of inoculation and solvent extraction was not found to be significant. The tensile strength of all the unextracted samples was significantly higher than that of the solvent-extracted samples, but there were no significant differences between the extracted samples. The 0-day control samples also proved to be significantly higher than the uninoculated and inoculated 84-day samples.

TABLE III.—Analysis of variance for tensile strength of 1.1 oz. rip-stop nylon after solvent extraction and exposure

Source of Variance	df	ss	ms	F	Prob. of F
Extraction	3	211.116	70.372	11.219*	>.05
Exposure	2	249.242	124.621	19.868*	>.05
Extraction and Exposure	6	86.735	14.456	2.305	N.S.
Error	108	677.420	6.272		
Total	119				

\*Significant at .05 level

TABLE IV.—Tensile strength—Mean ratings of 1.1 oz. rip-stop nylon in each experimental condition

	Unextracted	CHCl <sub>3</sub> Extracted	C <sub>2</sub> Cl <sub>4</sub> Extracted	CHCl <sub>3</sub> + C <sub>2</sub> Cl <sub>4</sub> Extracted	Main Effect of Exposure
Uninoculated 0-day control	52.38	49.35	51.74	49.55	50.77*
Uninoculated 84-day incubation	50.20	48.50	46.10	46.60	47.85
Inoculated 84-day incubation	49.90	48.65	46.15	45.65	47.59
Main effect of extraction	50.83	48.83	48.0	47.28	

\*Significant at .05 level

The warp-tears strength data in Tables V and VI show that significant differences were found among all variables as well as for their interactions. The significant interactions indicate that the various sample

exposure responded differently as a function of the extraction variable. The 0-day control samples were significantly higher than the uninoculated and inoculated 84-day samples extracted with chloroform.

TABLE V.—Analysis of variance for tear strength (warp) of 1.1 oz. rip-stop nylon after extraction and exposure.

Source of Variance	df	ss	ms	F	Prob. of F
Extraction	3	187.898	62.633	174.76*	>.05
Exposure	2	29.855	14.928	41.65*	>.05
Extraction and Exposure	6	22.185	3.697	10.30*	>.05
Error	108	38.711	0.358		
Total	119				

\*Significant

perchloroethylene, and the mixture of chloroform and perchloroethylene; however, the solvent-extracted samples were not significantly different from each other. Although the tear strength of the unextracted (control) samples was significantly higher than that of the extracted samples, a D of 0.89 shows that there is no significant difference in the tear strength between the unextracted 0-time controls and the uninoculated and inoculated unextracted samples.

As can be seen in Tables VII and VIII, measurements of the tear strength in the fill direction, all effects were significant. The significant interaction indicates that the various sample exposures responded

differently as a result of the extraction variable. No difference in the tear strength of any of the unextracted samples was observed before or after incubation. However, extraction with any of the solvents resulted in a severe loss in tear strength. Although significant differences were noted between the perchloroethylene, chloroform plus perchloroethylene extracted samples and their corresponding incubated samples, it can readily be seen that the major cause of tear loss was directly related to the solvent extraction process, and that incubation plays a far less significant role in this destruction since the uninoculated samples showed about the same relative loss as those inoculated with *P. janthinellum*.

TABLE VI.—Warp tear strength—Mean ratings of 1.1 oz. rip-stop nylon in each experimental condition

	Unextracted	CHCl <sub>3</sub> Extracted	C <sub>2</sub> Cl <sub>4</sub> Extracted	CHCl <sub>3</sub> + C <sub>2</sub> Cl <sub>4</sub> Extracted	Main Effect of Exposure
Uninoculated 0-day control	6.11	3.61	4.85	4.05	4.65**
Uninoculated 84-day incubations	6.45	2.85	2.78	3.25	3.83*
Inoculated 84-day incubation	5.88	2.99	2.20	2.77	3.46
Main effect of extraction	6.14*	3.15	3.28	3.36	

\*Significant at .05 level  
\*\*Significant at .01 level

#### Nylon as Sole Source of Carbon in Mineral Salts Medium

Since studies using Czapek Dox or PDA agars containing an ample carbon source for good mycelium and pigment production did not answer the question concerning the role of finishing oils in fungal contamination of nylon, it was decided to use a mineral salts agar or solution, with the nylon serving as the only source of carbon in the medium for further study of the problem.

Strips of 1.1 oz. nylon, some before and some after solvent extraction, were placed on mineral salts agar (Federal Test Method Standard No. 191, 1968, Method 5750 with and without 0.5% yeast extract), inoculated with *P. janthinellum*, QM 8464 and incubated for 84 days at 30°C. All failed to show any signs of growth or pigment production. These results would

indicate that parachute nylon does not contain nutrients in sufficient concentration to support the growth of *P. janthinellum*.

#### Solvent Residues from Nylon as Carbon Sources in Bushnell Haas Medium

Confirmatory evidence that growth could be supported by finishing materials if present in sufficient concentration was provided by further studies of concentrated solvent extracts of the fabric. Three samples of approximately 7 sq. ft. of cut-up nylon were individually extracted in a Soxhlet in absolute methanol, 2% sodium hydroxide, and perchloroethylene; a fourth sample was extracted for 2 hours in absolute methanol followed by 2 hours in chloroform. The methanol and sodium hydroxide extracts were evaporated down to dryness at room temperature. The other solvent extracts were concentrated down by

TABLE VII.—Analysis of variance for tear strength (fill) of 1.1 oz. rip-stop nylon after extraction and exposure

Source of Variance	df	ss	ms	F	Prob. of F
Extraction	3	222.789	74.263	214.63*	>.05
Exposure	2	4.823	2.412	6.97*	>.05
Extraction and Exposure	6	17.554	2.926	8.46*	>.05
Error	108	37.375	0.346		
Total	119				

\*Significant

TABLE VIII.—Fill tear strength mean ratings of 1.1 oz. rip-stop nylon in each experimental condition.

	Unextracted	CHCl <sub>3</sub> Extracted	C <sub>2</sub> Cl <sub>4</sub> Extracted	CHCl <sub>3</sub> + C <sub>2</sub> Cl <sub>4</sub> Extracted	Main effect of Exposure
Uninoculated 0 time	6.02	2.74	3.67	3.43	3.97
Uninoculated 84-day incubation	6.04	3.30	2.37	2.43	3.53
Inoculated 84-day incubation	6.01	3.50	2.56	2.12	3.55
Main effect of extraction	6.02**	3.18*	2.87	2.66	

\*Significant at .05 level

\*\*Significant at .01 level

evaporation at room temperature to approximately 10 ml. A 0.1 g. aliquot of the dried material or 1 ml. of the concentrated solvent extract was added as the only source of carbon to 20 ml of Bushnell-Haas mineral salts medium (Bushnell and Haas, 1941) in screw cap tubes, of each extract series, inoculated with a single pure culture of the 3 strains of *P. janthinellum*, QM 8464, 8791, and 6865, respectively, and incubated for 84 days at 30°F. At the end of the 84 days, all 3 individual strains showed slight to moderate mycelial mats, in all tubes. Controls of methanol, perchloroethylene, chloroform and sodium hydroxide in Bushnell-Haas medium showed no growth. All of these solvents were selected on the basis of their likelihood of coming into contact with parachute materials during processing of the fabric, manufacturing of the parachutes, or during packing, storage, cleaning for re-use, or use of the parachutes. Cates (1956) showed that all organic solvents (except carbon tetrachloride) even at high temperatures caused small or negligible losses in the tensile strength of parachute nylon. The present study indicates that materials extractable from parachute nylon fabric, when available in sufficient concentration, can serve as carbon sources for the growth of *P. janthinellum*. No attempt was made to further identify the nature of the compounds in the extracts, but it was assumed they contained one or more of the proprietary nylon finishes.

#### Microbial Susceptibility and Degradation of Nylon

Periodically, the question of microbial degradation of nylon textile materials becomes a topic for investigation as is evidenced by the literature cited. Usually involved are such factors as the source of nutrients when growth is observed on nylon and whether

physical damage to nylon occurs when fungal growth is found. There appears to be strong evidence that nylon polymers *per se* fail to support growth of microorganisms. Our studies with nylon cultured on mineral salts agar confirm those reported by Gray (1945) who could find no organisms out of 101 different genera and species able to grow when nylon 2 was used as the sole source of carbon. (Gray claimed that 6 organisms were able to use nylon as a nitrogen source.) Demmer (1968), using polyamide 6 and 6.6. sheets as the sole carbon source, also reported no growth of *Nigrospora sphaerica*. It is not disputed that growth on nylon does occur. The overwhelming impression, however, is that an ample supply of extraneous nutrients must be available to support such growth. Thus, in the laboratory, when a complete culture medium is used, growth readily takes place. Similarly, in a use situation, extraneous nutrient sources added to nylon fibers during the manufacture of nylon fabric to provide certain functional properties to the finished material or contaminants deposited on the nylon from the immediate environment can support growth. Thus, Lavrakas and Katz (1955) reported that lubricants used on parachute nylon lines supported growth and Reese *et al* (1950) attributed growth of *Tritirachium roseum* (QM 494) observed on nylon, to growth on "plasticizer" or on contaminating organic matter. Our studies suggest that the mere presence of nutrients is not necessarily enough to permit growth but that nutrients must be present in great enough quantities to permit ready growth. This is illustrated by the observation that nylon on mineral salts agar did not support growth; but concentrated solvent extracts of the nylon, presumably containing finishing oils, did support growth.

The more crucial question is whether growth on nylon causes physical degradation even though growth may be supported by nutrients other than the polymer itself. There is often a tendency to equate growth or staining of a material with physical degradation, but this does not always follow. It should be borne in mind that it is possible for a chromogenic fungus to produce a pigment which can be physically transferred to a microbially resistant synthetic polymeric film or fabric from the growth of the fungus on organic debris in close proximity to the material's surface. Many of the pigments produced diffuse into the surface of the material where they become irreversibly fixed, causing no damage to the material other than lowering its esthetic value. Leesment (1958) reported such an example where white polyethylene milk transport can covers developed a disagreeable red discoloration caused by a species of *Phoma*. Girard and Koda (1959) and Yeager (1962) reported on pink staining of vinyl and found this to be objectionable solely from an esthetic point of view. Hendey (1966) reported an interesting wine red stain associated with the decay of British Naval Service rubber-coated cotton life-rafts returned to the U.K. after use in Singapore. In this instance, however, *Myxotrichum deflexum* actually decayed the cotton component of the life-raft material and produced the red pigment as a by-product of its metabolism. Other chromogenic fungi capable of staining plastics include *Penicillium rubrum*, *P. citrinum*, *P. purpurogenum*, *Streptomyces rubireticuli*, the aspergilli, and the dematiaceous fungi (Turner, 1967).

### Conclusion

Our studies confirm the previously observed pink staining of parachute nylon by *P. janthinellum* but they fail to confirm the accompanying tensile loss reported by Dayal *et al* (1962) and Nigam (1965), nor could we demonstrate any tear loss attributable to microbial activity. In view of the fact that the nylon polymer *per se* does not seem to support growth and pigment production, it is theoretically conceivable that in the presence of growth supported by extraneous nutrients, the nylon could be degraded by metabolic products elaborated by the fungus, i.e., organic acids or the extra-cellular pigment itself. Should these have been responsible for damage, we feel that discernable physical changes would have occurred after the long incubation periods we used, i.e., 84 days, and the heavy staining and growth observed. Because Demmer (1968) reported erosion of polyamide 6 film by *Nigrospora sphaerica* and Allakhverdiev *et al* (1968) reported significant tensile strength loss of polyamide PK-4 in liquid medium by penicillia and aspergilli, it could be argued that our findings are sound only for the specific organisms we used. We do not feel that this is valid. In our laboratory, we give great credence to soil burial as an assay tool for determining resistance of materials to microbial degradation, Kaplan (1967). Materials in soil burial are subjected to a wide variety of microorganisms and the susceptible materials are

readily degraded. When we cultured parachute nylon on Czapek Dox agar for 42 days with each of the strains of *P. janthinellum* used in this study and then buried the same samples in soil for 42 additional days we observed no significant changes in tensile strength for any of the samples tested. This would indicate that the fabric was resistant to physical damage by microorganisms in general. This observation is in consonance with similar observations which we have repeatedly made over the years with a variety of nylon materials assayed in soil burial.

Although we note reports in the literature of microbial damage to nylon materials, we can find no evidence from our own studies that nylon textile materials are seriously degraded by microorganisms in actual field use.

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