Effects of deodorants on perspiration odor retention and selected properties of polyester and polyester/cotton blend fabrics

by

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Signatures have been redacted for privacy

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INTRODUCTION

The absorption and retention of odors by textile fabrics is an old and widespread problem. Textile manufacturers and consumers are concerned with odors in use as well as in storage. Some dyes and finishes on clothes have distinctive odors of their own which combine with body odors to give an entirely different odor while other finishes contain compounds which are subject to bacterial decomposition and consequently increase the amount of odor perceived on the wearer. Of the various odors associated with the human body, that of perspiration is the most common and distinct. In recognition of this problem, attempts have been made to control the conditions responsible for the development of odors on the body. An attempt is made in this study to determine the effectiveness of one of these odor control products in checking the build up of odors in shirts of two fiber contents.

As Fiedler (1969) observed, odor plays a very important part in life; for animals and man in his primitive state, survival may sometimes depend on the ability to discern the odor of preys and preying animals. This no longer holds true for the civilized man, but odor still plays an important part in both his personal and social life; it can be a cause of his acceptance or rejection because people will reject others when they find their personal odors offensive. The sense of smell is played upon in most activities which involve the psyche. In the Catholic church, the burning of incense creates an atmosphere conducive to worship and many of the oriental religions have incense burning as part of the ritual of worship. This involvement of the psyche in odor causes it to be retained in the memory longer than things perceived by sight or hearing. There is some controversy as to the part odor plays in sex. In the upper Palatinate, a young man will tuck a nosegay under his armpit to give it his personal odor before giving it to his lover, the nose rub of the Asians is imputed with the same motive. In many cultures, however, the trend is toward de-emphasis of natural body odors and most people would agree with Thomas (1969) when he stated that excessive concentration of odors was always unpleasant. McCord and Witheridge (1949) agreed that although odor was not dangerous to health, to be reckoned a neighbor, one had to be not only not dangerous but also not disagreeable.

Perspiration odor is associated with the secretion of the apocrine sweat glands which are supposed to be most prominent among the Negroes, who have a higher number of these glands than any other human race (Kuno, 1934). The quantity of insensible perspiration is 700 cc daily for adults. On hot summer days, however, hardworking laborers perspire this amount hourly. This is especially significant for the Negro in the tropics where the way of life coupled with a high temperature of 26.7°C (80°F) most of the year cause profuse sweating.

With increased emphasis on ease of care of garments, there has been an increased demand for polyester and polyester/cotton blend fabrics on the Nigerian market. The production of polyester in the United States alone increased from 41.0 million yards in 1965 to 64.1 million yards in 1970 (D'Alexandro, 1972). A part of this increase appeared on the Nigerian market since Nigeria imported polyester mainly from Britain and the United States. This fabric has excellent resistance to wear, but this characteristic will constitute a social problem due to the long period of wear unless the build-up of odor can be controlled. Along with the increased production of polyester, there has also been an increase in the production and sales of deodorants, a product also imported by Nigeria from Britain and the United States. Alexander (1969) forecast an increase in production of deodorants from 220 mil-units in 1967 to 620 million units in 1970 for the United States and from 18 million units in 1969 to 22 million units in 1970 for the United Kingdom. It seemed appropriate to study the performance of deodorants and polyester fabrics under certain conditions. Therefore, the objectives of this study were:

1. To evaluate odor retention in fabric after wearing and laundering.
2. To evaluate strength retention of fabric after wearing and laundering.
3. To determine color fastness in specified areas of the garments.
4. To determine the durable press ratings of the garments.

5. To identify the odor causing compound in the garments.

The study was carried out under the following assumptions:

1. That the participants would refrain from using other preparations that would mask odor.
2. That the participants would wear all garments for the specified period of time.
3. That the different nondeodorant soaps used by the participants would have comparable antibacterial strength.

The limitations recognized in the study were:

1. The research might yield different results if carried out in the hotter months of the year rather than in the colder months as was the case.
2. The results might be different if the Nigerian subjects were on their customary diet.
3. Machine washed samples might yield different results from hand washed samples which would be the case in a Nigerian home situation.

Specific hypotheses related to the above objectives were as follows:

1. There is a build up of odor in garments over a time period.
2. Garments worn by subjects wearing deodorant have less odor build-up than those worn by subjects without deodorant.
3. The 65/35% polyester/cotton blend garments have less

odor build-up than the 100% polyester garments.

4. The garments worn by women have more odor build-up than the garments worn by men.
5. Garments worn by Caucasians have less odor build-up than garments worn by Negroes.
6. Garments worn by subjects not using deodorant retain less of their original strength than garments worn by subjects using deodorant.
7. The 100% polyester fabrics retain more of their original strength during wearing and laundering than the 65/35% polyester/cotton fabrics.

REVIEW OF LITERATURE

Literature concerning the effects of perspiration on textile products is limited. Studies related to the formation and perception of perspiration odor, the reaction of polyester to soils of an oily nature and the performance of durable press fabrics under different laundering conditions are reviewed in this chapter.

Odor Perception, Formation and Control

Odor perception in man is the function of a highly specialized olfactory system. Odor is perceived as a result of the interaction between the olfactory epithelium and the odor stimulus. As the odor laden air passes through the turtuos channels of the nose, a small portion of it reaches the epithelium which is located in the narrow olfactory cleft in the upper part of the nose. Stuiver (1958) estimated that only about 2% of the material contained in a single sniff will reach the sensitive area. Odor molecules dissolve in the fluids bathing a small area of the nasal cavity. This sets up impulses through the olfactory nerves to the brain which correlates it with some past experience. In man, the peripheral receptor cells number 5×10^7, each possessing a number of hairlike extensions. There is little evidence for differentiation between the cell parts which might be held responsible for odor differentiation (Harper et al., 1968).

Many theories have been put forward by researchers in various fields concerning the nature of odor. Among these is Amoore's stereo-chemical theory which stated that each primary odor has a characteristic size and shape. Seven primary odors were identified and, in a later work, this number was enlarged to twenty or thirty (Venstrum & Amoore, 1968; Amoore, 1970). On the basis of these theories, instruments have been designed to measure odor but none has yet achieved a sensitivity comparable with that of the human nose. For this reason, the nose remains the best instrument for judging and the use of the judgment of a trained panel on a five, six or seven point scale is still recommended (Thomas, 1969).

Heller in his 1763 Classes odorum, identified three main groups of odors: the sweet smelling or ambroisic odors, intermediate odors and stenches. The last group included the odor of animal perspiration (Harper et al., 1966). This recognition accorded to perspiration odor as a distinctive group was later confirmed by Amoore when he identified sweaty odor as one out of his postulated thirty (Amoore, 1970). Perspiration is the secretion of the ecrine and apocrine sweat glands of the body which are located in the subcutaneous layer of the epithelium. Kuno (1934) differentiated between the ecrine and the apocrine glands. He described the ecrine glands as secreting water with some salt and mineral while the apocrine glands discharge a fatty substance which contains nitrogen. These glands are found only in the axillae and become active during puberty while the ecrine glands are found all over the body and start functioning early in life (McCord and Witheridge, 1949). There appears to be some controversy among scientists as to the part played by the apocrine glands in odor formation. Kuno (1934), McCord and Witheridge (1949) believed these glands to secrete an odorous substance of some sexual significance. However, recent opinions state that perspiration odor is caused by bacterial decomposition of apocrine perspiration. The alkaline medium provided by the apocrine secretion facilitates decomposition by bacterial action whereas ecrine perspiration is acid and thus not subject to bacterial decomposition (Keubler, 1969; Fiedler, 1969; Barail, 1946, 1947). Barail also stated that substances in food can decompose to give off odor which can be smelled in perspiration, for example, the garlic odor of Europeans. There is a lack of agreement as to the effect of the nature of food on body odors. While Barail (1946) propounded the theory that a predominantly vegetable diet increased the alkalinity of perspiration making it more odorous on decomposition, Kuno (1934) and McCord et al. (1949) attributed odor to a high consumption of meat, hence the odorlessness of Chinese who were on a predominantly vegetable diet.

There also seems to be some racial differences in perspiration odor. Scientists believe, though no experimental evidence was shown, that the Negroid race is more odorous than the other human races. Their opinions differ, however, as to the cause. Kuno (1934) and McCord and Witheridge (1949) claimed that the Negro had a higher number of apocrine glands and that dark skinned people were generally more odorous than light skinned people. This principle applied also within the same race, i.e., brunettes were more odorous than blonds, the young and old were less odorous than the middle aged individuals and the fat and lean individuals were more odorous than the average weighted individuals. Fiedler (1969), on the other hand, stated that perspiration odor is due solely to the decomposition of the protinous and fatty substances contained in perspiration by the gram positive, bacteria, coagulase-negative staphylococci and diphtheroids present on the skin and in the ducts of the sweat glands. When these ducts are large, as is the case in Negroes, decomposition takes place rapidly giving rise to odors. Also, since hair impedes cleaning and anchors bacteria, it is believed to encourage odor.

There is some uncertainty as to the exact composition of perspiration. The reason for this uncertainty lies, first of all, in its combination with the secretion of neighboring glands as it passes out of the excretory ducts and, secondly, in its variability both between and within individuals from one part of the body to the other and in the same part at different times of the day. McCord and Witheridge (1949) described the make-up of perspiration as follows:

	Parts		
Water	991	Organic nitrogen	1.2
Sodium chloride	5.2	Calcium phosphate	0.2
Urea	1.2	Potassium carbonate	0.1
		Sulphates	0.6

Formic, propionic, capronic, caproic, butyric, valeric, caprylic, palmitic and stearic acids are also contained in small quantities and the pH ranges from 3 to 7.5. Barail (1946) gave the composition as 98% water and 2% solids. In addition to the above compounds he listed ammonia, uric acid, cholesterol, traces of creatin, serin aromatic oxy acids, ethereal sulphates of phenol and skatol, albumen, nicotinic acid and some vitamins. Using these compounds, he was able to reproduce perspiration odor by infecting a laboratory sample of perspiration with the appropriate bacteria. Alexander (1969) stated the composition as 98-99% water and 1-2% sodium chloride and lactic acid. Upon decomposition, iso-valeric butyric acids, mercaptans, indoles, sulphuric acid and phosphine were given off. Fiedler (1969) did not indicate the percentages but gave the solids as proteins and fatty substances which decompose into short chain fatty acids, ammonia, mercaptans and other sulphurous substances. His view was strengthened by Amoore (1970) who proved that the sweaty odor reached a minimum threshold in fatty acids having between four and five carbon chains.

In the laboratory, under sterile conditions, perspiration does not affect textile products adversely. However, contaminated perspiration causes fabrics to rot aside from producing offensive odors. The high pH plus a speedy decomposition of sweat and fabric finish can sometimes end in a rapid decomposition of fabrics. Decomposition of fabrics is generally slowed by laundering because of three actions: sweat and fabric finish are diluted; solid particles are dislodged mechanically; final rinsing flushes them away. Fabrics should be washed following each period of contamination. The only complete control of odor formation and accompanying fabric decomposition is achieved by treating the fabric with an antiseptic (Barail, 1947). The laundering process is not necessarily this effective in dislodging bacteria and solids from perspiration as Wieskell (1971) showed. She inoculated fabric samples with three species of bacteria and washed them together with sterile fabric samples at different water temperatures. She found (a) that the bacteria survived the wash temperature and mechanical action and (b) that there was transfer of bacteria from the contaminated samples to the sterile samples. Rounds et al. (1973) also found that there was a build up of particulate and oily soils on fabric samples soiled in keolite clay and synthetic sebum which were washed after aging for four days.

Using fabrics made of acetate and rayon, Barail (1947) showed that treatment of fabrics with an antiseptic is an effective preventive measure against odor formation. He treated the samples with 250 chemicals. After treatment, these fabrics were put in tubes of sterile broth without taking aseptic precaution and incubated at 37°C for seven days, after which the tubes were examined for growth. The fabrics were washed up to forty times without retreatment. They were incubated as indicated above and observed after every five launderings. The results showed that the fabrics remained sterile all through the forty laundering periods except for the "rayon acetate" which became septic in the fortieth laundering. These chemical compounds were also found to prevent odor formation due to bacterial decomposition of perspiration. Barnes (1931) studied the effects of perspiration on fabrics used for summer dresses. Samples of the fabrics were immersed in laboratory prepared perspiration, then dried. Some of the samples were aged and others washed after drying. Her results showed that a significant amount of strength was lost as a result of the aging.

As a result of the concern of textile manufacturers about the damaging effect of perspiration on textile fabrics, attempts were made to devise means, other than underarm padding, to minimize this effect. Alexander (1969) outlined three approaches to the perspiration problem. The first approach was the systematic administration of antichlinergic compounds which reduce the flow of perspiration. This is a medical approach that is used in the control of hyperidrosis and therefore is not of concern in this study. The other two approaches are taken by the cosmetic industry. The first aims at stopping the excretion of perspiration in certain parts of the body where it constitutes a problem, namely in the axillae, genitalia and the soles of the feet. Aluminum compounds were discovered to have antiperspirant qualities, i.e., the ability to stop the secretion of perspiration. Alexander (1969) stated that aluminum compounds were safe for daily use on the skin and sufficiently soluble and effective in inhibiting the flow of perspiration, an aqueous solution had a pH of 3.5 to 4.5. Aluminum hexahydrate had been known as an antiperspirant for a long time but was considered too acid for fabrics. Heterocyclic aluminum compounds which were not too corrosive were discovered by the Chattanooga Chemical Company. According to Carsch (1971), the first antiperspirant was odorono liquid which was made of water and aluminum chloride in 1920. Between 1937 and 1938, Arrid, which was composed of aluminum sulphate buffered with urea, was manufactured. Aluminum chlorhydroxide was first used in 1948 and is now the active ingredient in antiperspirants. Zinc compounds and zinconium salts have also been used. Aluminum compounds are antibacterial in action because they hydrolyze to a low pH which checks bacterial growth and can also check odor by chemically combining with odoriferous compounds (Alexander, 1969).

The second approach is the use of deodorants. A straight deodorant is a substance that eliminates odor without adding any masking odor of its own. The other type of deodorant acts by chemically reducing or supressing the odor and most of the deodorant for underarm use is of this type. The cosmetics industry mainly produces deodorants with antiperspirant qualities. Kuebler (1969) contends that deodorants will prevent odor but will not stop the odor once it is present. These products are also designed to deodorize and lend a new and pleasant odor. The two methods that he referred to were, first, to use aluminum salts to inhibit the flow of perspiration and, second, to destroy the bacteria. Microbials differ in their effects on different micro-organisms and since the normal skin flora is 99.9% gram positive bacteria, a product affecting only these can be used. Hexachlorophene was the most widely used bacteriacide in aerosol deodorants. It is scentless and effective in low concentrations. He gave the formula for a deodorant as:

Hexachlorophene	.4	-	.5%
Isopropylene mystrate	2.0	-	3.0
1,2-Propylene glycol	3.0	-	5.0
Perfume	0.6	-	2.5
Alcohol	94.0	-	89.0

30% solution is filled out with 70% propellant.

Other antibacterial compounds used are tetramethyl thuiram disulphide-quaternary ammonia (TMTD) compounds, 8-hydroxyquinoline, 3,4,4-trichlorocarbanilide, diaphene. TMTD compares well with hexachlorophene in attacking

Micricocus aureus and gram negative organisms. Neomycin 3.5 mg/g inhibits odor but is used on only super sensitive skins. Some copper, aluminum and magnesium salts absorb decomposition products of perspiration thus destroying odors which were present. They also block bacterial metabolism of proteinous matter thus preventing further malodor.

Deodorants are designed for use by both men and women. Carsch (1969) identified twenty-seven products, seven of which were designed exclusively for men. The difference, however, was in perfume and package design rather than in the active ingredient. One of these products, Right Guard, was produced for the whole family but the perfume had a masculine bias.

Reaction of Polyester to Soil of an Oily Nature

Research indicates that the laundering process does not remove all the soil from fabric. The retained soil, composed of free and combined fatty acids, is found in areas where clothes touch the skin, namely on cuffs, collars and underarm areas, and with time accumulation of soil often results.

Powe and Marple (1960) extracted the organic soil that had accumulated on cotton garments and analyzed it for free and combined fatty acids using the gas liquid chromatography. They found that the fatty acid composition of this material was similar to sebum and hair fat and was fairly uniform even though the samples came from different sources and geographical locations. The build up of this fatty soil is facilitated by certain oleophilic fibers and finishes. Of these fibers, polyester has been of concern to researchers because of its wide usage and its use in combinations with cellulosic fibers for durable press and wrinkle resistant finishes which, in themselves, are oleophilic. When soils accumulate in the underarm area they increase the material available to bacteria for decomposition provided favorable conditions exist.

Sontage et al. (1969) studied the phenomenon of soil build-up on cotton and polyester/cotton blends. The blend consisted of two sets of samples, one finished for durable press and the other unfinished. These were soiled with clay and synthetic sebum and then laundered. The process was repeated five times and the samples were analyzed for soil retention. The results showed that the treated blend soiled more easily and retained more soil than the unfinished blend but that cotton retained more soil than the 100% polyester. Rounds et al. (1973) obtained similar results. Samples of 65/35% and 54/46% polyester/cotton blend fabrics were soiled with kaolite clay for one hour, rinsed in deionized water and soiled in a solution of synthetic sebum in chloroform. They were aged for four days, laundered separately five times in a Terg-O-Tometer and the reflectance reading was taken. They found that all the fabrics built up soil after five launderings but that the rate of the build up slowed down after the first two launderings. They attributed this to the saturation of the oil sites on the fiber. They also confirmed

Sontage's finding, that the polyester/cotton blend retained more soil than the 100% polyester. Lebhard and Morris (1970) conducted similar studies using radioactive sebum, 100% cotton and a 65/35% polyester/cotton blend with a durable press finish. Soiled samples were aged and laundered in a Terg-O-Tometer and soil removal evaluated at 0, 5, 10 and 30 soiling-laundering cycles. The results showed that there was a build up of soil on all fabrics but that the rate of the build up decreased through thirty launderings. The cotton fabric retained less soil after the first laundering but accumulated more soil than the durable press fabrics by the thirtieth laundering.

Schott (1969) attributed the higher level of soil retention to the method of soiling. The retention of the solvent used to dissolve the sebum in the lumen of the fibers made the sebum more difficult to remove by ordinary laundering processes. Brown et al. (1968) believed that the fiber and fabric structure were also contributing factors. They investigated staple and filament polyester and 100% cotton fabric which they soiled with sebum-type oil and a second set of garments of the same fiber content which were used as coat-like uniforms in a fish and chip establishment. They were able to demonstrate that staple fibers absorbed more oil than filament fibers. Their views were confirmed by Huisman and Morris (1972) when they showed that abraided durable press fabrics retained more oily soil than their laundered counterparts. This was due to the fact that the abrasion provided more oil adsorption sites. The cotton, on the other hand, retained less oil when abraided than when laundered. They concluded that the cotton fibers disintegrated when abraided and thus released the soil trapped within and between the fibers.

The retention of oily soil is also affected by wash water temperature. Bubl (1970) soiled twenty samples of 100% cotton with an oily mixture and laundered them with twelve unsoiled samples at two water temperatures, $30^{\circ} \pm 3^{\circ}$C ($70^{\circ} \pm 5^{\circ}$F) wash and cold rinse and $60^{\circ} \pm 3^{\circ}$C ($140^{\circ} \pm 5^{\circ}$F) wash and warm rinse, using cold water detergent and regular detergent. She found that as water temperature increased, soil removal was facilitated and soil redeposition inhibited. Water temperature was more important than detergent type in soil removal and redeposition.

PROCEDURE

Design of Study

To obtain the information pertinent to the objectives, a wear study was conducted during the months of April and May,19 1974. Six Nigerian subjects and six American subjects composed of an equal number of males and females, were assigned two shirts each. One set of shirts was made of 100% polyester and the other was a 65/35% polyester/cctton blend. A subject from each group acted as a control by wearing the shirts without deodorant. The shirts were laundered as specified in the AATCC test method 124-1974 after each wear period.

The garments were subjectively evaluated for odor retention before and after the 5th, 10th, 15th, 20th and 25th launderings by an untrained panel of twelve judges and for durable press performance by a trained panel of three judges. By comparing the ratings of the judges it was possible to determine the effects of deodorant on odor retention.

Equipment Used

<u>Speed Queen Automatic Washer</u>

McGraw Edison Company. Power specifications for the washer were 110/115 volts, 60 cycles, 8 amperes. The machine was a top loading agitator design with selective controls that permitted manual control of the wash process. The machine offered a choice of two wash cycles, regular and permanent press; two agitation speeds, brisk (68 oscillation per minute); and gentle (44 oscillations per minute); two spin speeds, fast (625 revolutions per minute) and slow (410 revolutions per minute) and three wash temperatures, hot, warm and cold.

Speed Queen Dryer

McGraw Edison Company. Power specifications for the dryer were 120/240 volts, 60 cycles, 24 amperes. The dryer offered a time dry cycle which operated for the number minutes for which the timer was set and a permanent press cycle operated for thirty minutes. It also offered a choice of drying temperatures for fabric type. The temperature selections available were for delicate fabric, normal fabric and air fluff (no heat).

Fahrenheit thermometer

Chicago Apparatus Company. The temperature recordings were made as water entered the washer and at the beginning of the rinse cycle.

Milway double beam trip scale

Chicago Apparatus Company. The scale was used to weigh the detergent. The weight was expressed in grams.

Tensile strength tester

Henry L. Scott and Company. The Scott Tester was used to conduct dry breaking strength by the ravel strip method for the 65/35% polyester/cotton blend fabric and bursting strength for the 100% polyester knit garments.

Durable press replicas

A set of durable press surface replicas was used to determine the durable press ratings using the AATCC method 124-1973.

Yarn counter

Alfred Seuter Company Textile Instruments. The yarn count of the garments was taken originally and after twenty-five launderings.

Miscellaneous equipment

Scissors

Beaker

Hangers

Laundry marker

Meter stick

Supplies

Synthetic granular detergent

Tide by Procter and Gamble, designed for use in hot water.

Fabric softener

Liquid Downy for conditioning the fabric.

Deodorant

Right Guard by Gillette, scented.

Fabrics

Five white and four blue long sleeve blouses of 65/35% polyester/cotton blend fabric with a thread count of 147 warp and 56.5 filling.

Three brown, three green and two burgundy colored long sleeve shirts of a 65/35% polyester/cotton blend fabric with a thread count of 112 warp and 72.85 filling.

Five red and five yellow long sleeve blouses of 100% polyester double knit fabric with a thread count of 39.5 courses and 41.5 wales. Ten blue long sleeve shirts of a 100% polyester double knit fabric with a thread count of 38.4 courses and 37.85 wales.

Experimental Procedure

The shirts and blouses used in the study were of a 100% polyester and a 65/35% polyester/cotton blend fabric. A deodorant, Right Guard, was chosen because it was the only product designed for use by both men and women. Each of the six female subjects was randomly assigned two blouses, one from each fiber content and the same process was repeated for the men; the garments were coded. One subject from each group acted as control by wearing the shirt without deodorant, while the rest were assigned a can of aerosol Right Guard. Each subject had at least one shower but not more than two a day, using a nondeodorant soap. Subjects wearing deodorant applied it every morning, immediately after a shower according to the manufacturer's specifications, i.e., holding the can six inches from each underarm and spraying for two seconds. The shirts were put on after the application and worn for a period of not less than eight hours. For those in the nondeodorant group, the shirts were put on after the morning shower and worn for the same period of time. Each fiber content was worn on alternate days. The shirts were collected at the end of the day and laundered in the laboratory using the AATCC test method 124-1973. The shirts were sorted according to color and the cuffs and collars were pretreated by applying some detergent and rubbing between the hands. Each load was brought up to 6 lbs with a dummy load and laundered at a temperature of $60^{\circ} \pm 3^{\circ}C$ ($140^{\circ} \pm 5^{\circ}F$) with 40 g of detergent, using the permanent press cycle. Each load was given a single overflow deep rinse and one power spray rinse at a temperature of $41^{\circ} \pm 3^{\circ}C$ ($105^{\circ} \pm 5^{\circ}F$). Fabric softener (30.4 g) was added to the rinse water. The loads were dried for thirty minutes on the permanent press setting and normal heat, as specified in the AATCC test method 124-1973.

Subjective evaluation for odor

The shirts were evaluated for odor retention at the 5th, 10th, 15th, 20th and 25th launderings. To determine the amount of odor accumulated in the shirts, they were evaluated before and after laundering by a panel of twelve untrained judges composed of Iowa State University graduate students, faculty and staff of the Textile and Clothing Department. The shirts were laid out on tables in a well ventilated room. Each judge smelled the two underarms of each shirt and rated the amount of odor perceived on a four point scale independent of the other judges. This process was carried out before and after laundering for each set of shirts. Twelve shirts were rated on each day. The identity of the wearer of the shirts was kept from the judges to avoid bias.

Durable press ratings

The performance of the durable press finish was rated by a panel of three trained judges drawn from graduate students in the Textile and Clothing Department at Iowa State University. The shirts were evaluated at the 5th, 10th, 15th, 20th and 25th launderings. The shirts were mounted on a board at a height of 52 in. from the floor. A pair of the AATCC durable press surface replicas was mounted, one on either side of the shirt, 6 in. from the shirt with the middle of the replica corresponding with the middle of the shirt. A single fluorescent bulb mounted above the shirt provided the light for the evaluation. Each judge evaluated each shirt by comparing the shirt with the surface replicas. The number of the replica most closely resembling the state of the shirt was assigned to the shirt. The average rating of the three judges was taken for each shirt.

Evaluation of strength

The shirts were tested for strength according to the ASTM standard D 1682, using the ravel strip method for the polyester/cotton blend garments. The ball bursting method was used for the polyester knit as specified in the standard. To determine the loss of strength due to perspiration, samples were taken from the tail area to represent loss of strength due to wear and from the underarm area to represent loss of strength due to perspiration and wear. The difference between the two measurements was taken for changes in strength due to perspiration. Samples were also taken from the original shirts for comparison.

For the ravel strip method, five samples, 5 in. long and 1.25 in. wide were cut with the length in the warp direction and another five samples with the length in the filling direction. Two sets of samples were taken from each shirt, one from the tail area and another from the underarm area. The samples were ravelled down to 1 in. width by taking approximately the same number of yarns from each side. They were coded and conditioned overnight at a temperature of

$21^{\circ} \pm 1^{\circ}C$ ($70^{\circ} \pm 2^{\circ}F$) and a relative humidity of 65 ± 2%. The samples were tested on the Scott Tester under standard atmospheric conditions.

Bursting strength

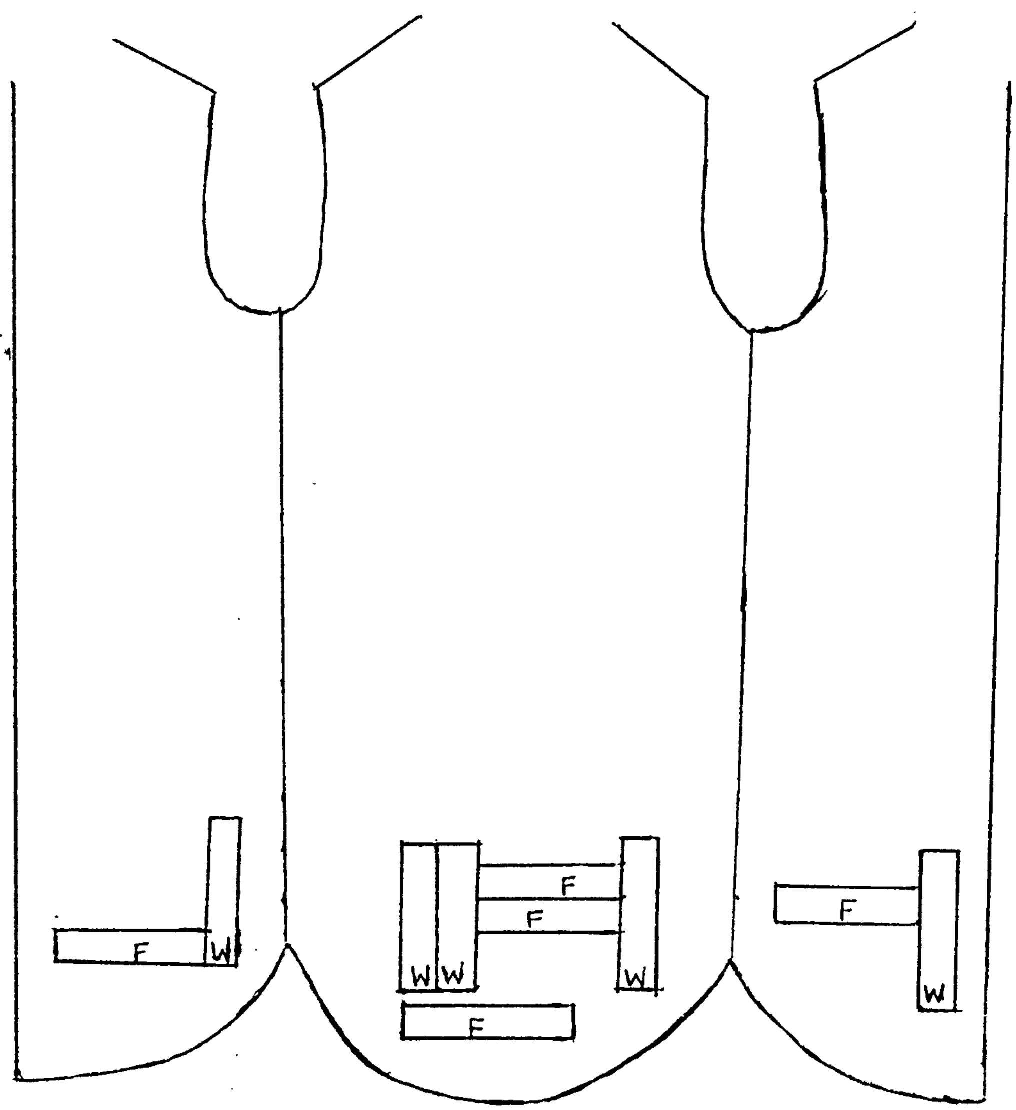
The bursting strength of the knitted fabrics was tested on the Scott Tester using the ball bursting attachment. Samples 4 in. x 4 in. were drawn from the underarm and tail areas of each shirt. The samples were conditioned at a temperature of $21^{\circ} \pm 1^{\circ}C$ ($70^{\circ} \pm 2^{\circ}F$) and a relative humidity of 65 ± 2% and tested under standard atmospheric conditions. The bursting strength was recorded and an average taken for each set of samples.

Analysis of odor compound

The odor from the unwashed samples was extracted by soaking the samples in dilute (0.1N) sodium hydroxide. The solution was centrifuged from the cloth from a "spin thimble". The alkaline solution was acidified and injected on a gas chromatograph which had a six foot column packed with 15% Carobwax 40 M-3% phosphoric acid. The column temperature was started at room temperature and raised 6°/min to $150^{\circ}C$. Fractions of the gas were smelled as they issued from the column.

The alkaline extract was converted to a decyl ester for quantitative gas chromatography with sulfuric acid as a catalyst (Earl Hammond, Department of Food Technology,

Figure 1. Areas of the polyester/cotton shirts from which samples were cut for testing (F = filling; W = warp)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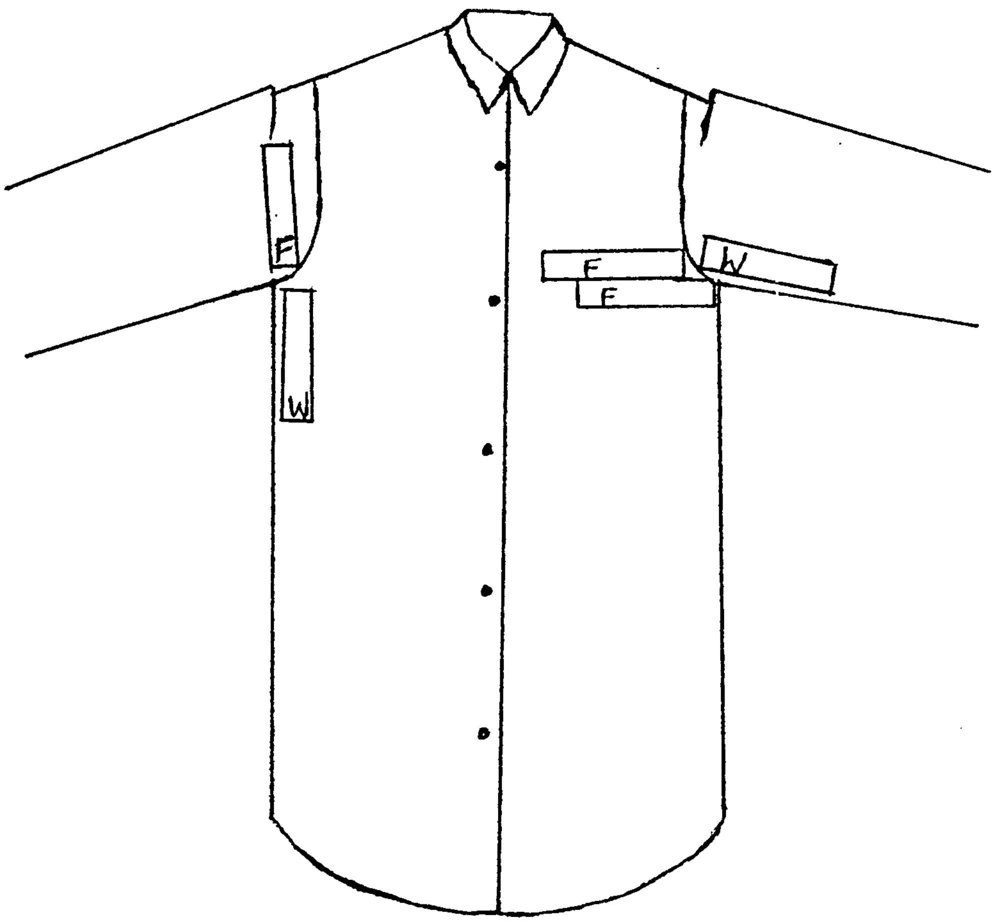

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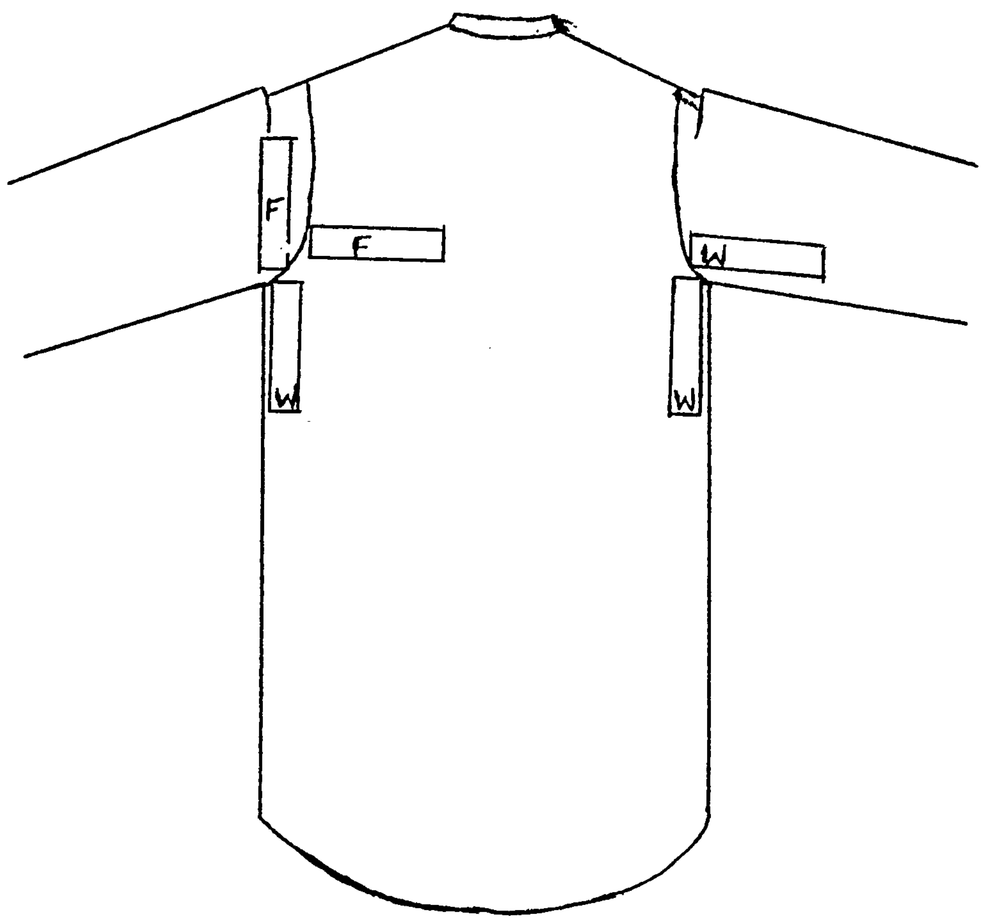
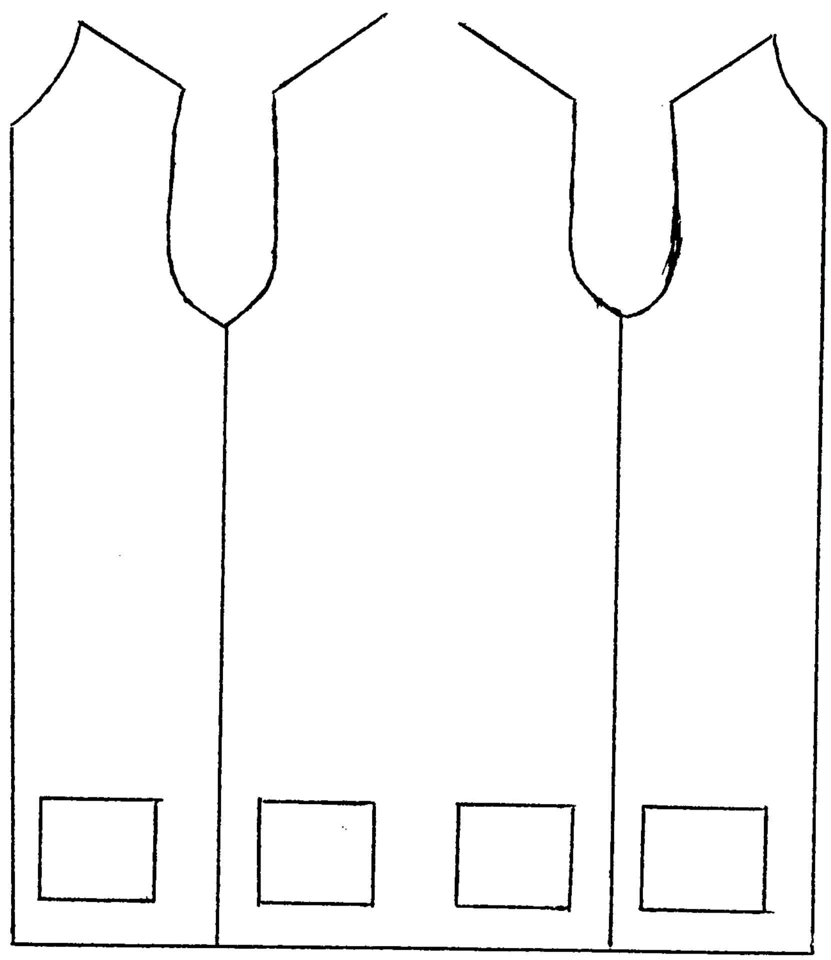


Figure 1. (Continued)

Figure 2. Areas of the polyester shirts from which samples were cut for testing (F = filling, W = warp)



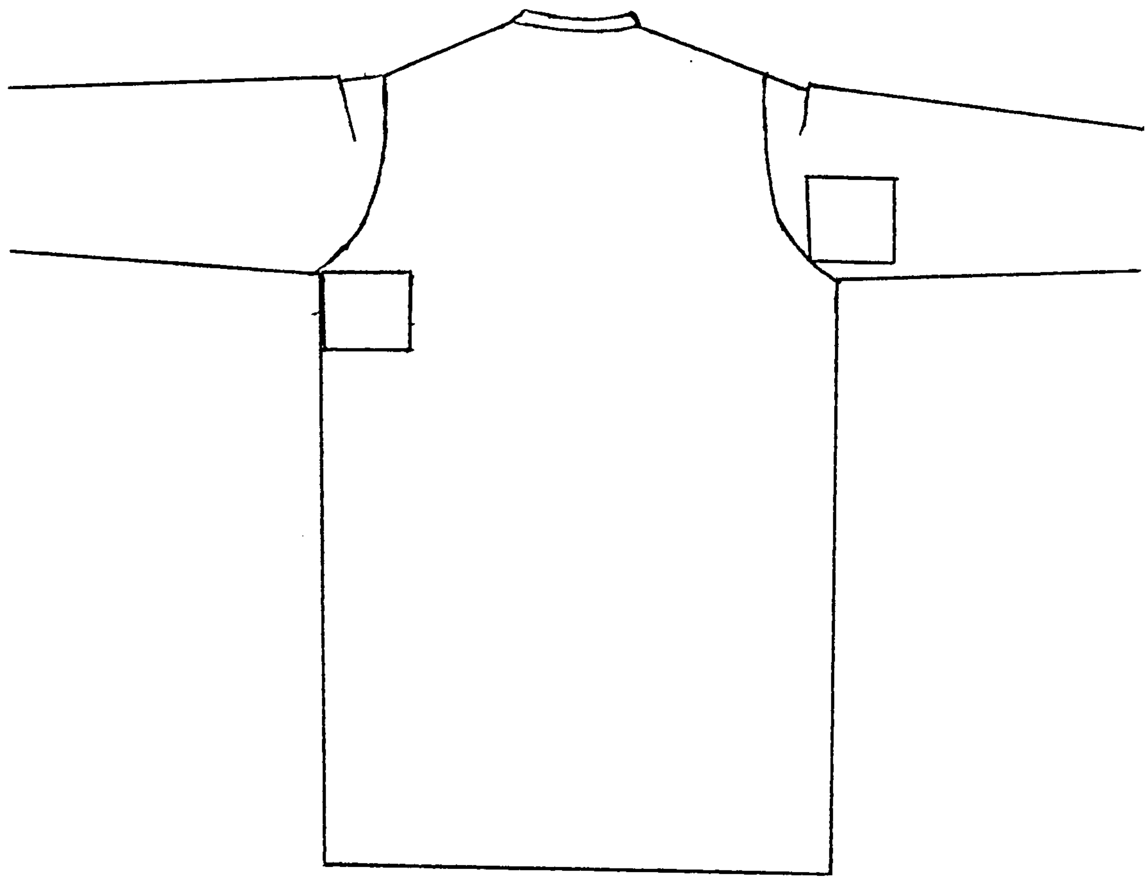


Figure 2. (Continued)

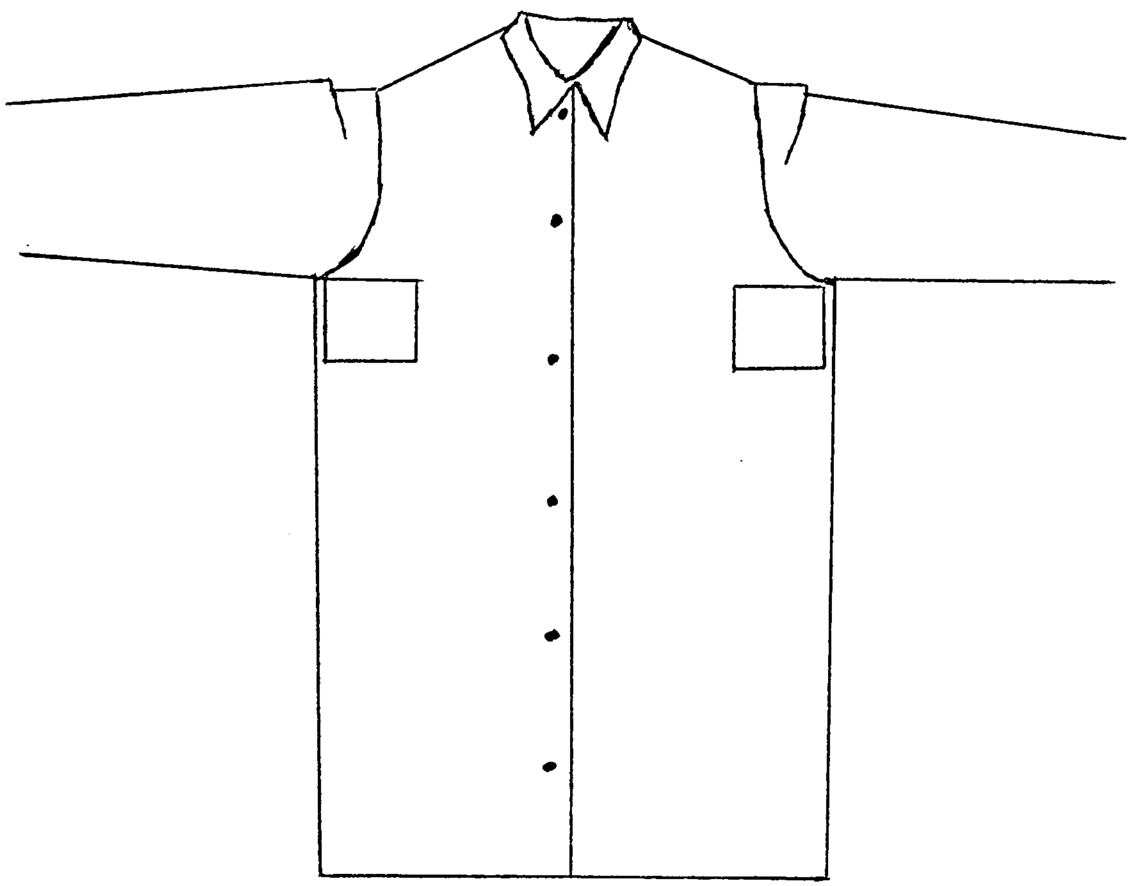


Figure 2. (Continued)

Iowa State University, Ames, Iowa, Personal communication, 1974).

Evaluation of color retention

The shirts were evaluated for changes in color in the underarm areas using the gray scale for color change as specified in the AATCC test method 15-1973. To determine what changes were due to wear and what changes were due to perspiration, the tail areas of the shirts were also evaluated. The difference between the two readings was taken for changes due to perspiration.

Analysis of data

To determine the effect of deodorant, sex and composition on odor retention, a multifactor experimental design with repeated measures was used in the analysis of variance. The levels were:

A (2 levels): Deodorant and nondeodorant

B (2 levels): Male and female

C (5 levels): Time, 5th, 10th, 15th, 20th and 25th launderings

D (2 levels): Wash, before and after laundering

E (2 levels): Composition; 100% polyester, 65/35% polyester/cotton blend

F (2 levels): Race; Caucasian, Negroid

The same multifactor experimental design with repeated measures was used to determine the effect of deodorant and race on odor retention and the effect of fiber content on odor retention. Comparisons were made to determine significant differences between two means, using the following equation:

$$t = \frac{\bar{X}_i - \bar{X}_j}{sp(\frac{1}{M_i} + \frac{1}{M_j})}$$

where: $\bar{X}_i$ and $\bar{X}_j$ = means 1 and 2 respectively.

sp = pooled estimate of variance.

M_i and M_j = number of observations in treatments i and j.

To determine the durable press performance of the two sets of shirts, the scores for each shirt were multiplied by ten for ease in computation and the analysis of variance was used to determine the level of significance.

RESULTS

Analysis of odor and strength retention of the polyester and the 65/35% polyester/cotton blend shirts were made to test specific hypotheses and to achieve the following objectives:

1. To evaluate odor retention in fabric after wearing and laundering.
2. To evaluate strength retention after wearing and laundering.
3. To determine colorfastness in specified areas of garments.
4. To determine the durable press ratings of garments.
5. To identify the odor causing compound.

Build-up of Odor in Garments

The mean scores for the strength and unpleasantness of odor present in the shirts before and after laundering were graphed in Figures 3 and 4. The following hypothesis was tested:

Hypothesis 1: There would be a build-up of odor in the garments over a period of time.

Analysis of variance showed that a significant difference existed in both the strength and unpleasantness of the odor present in the garments at the 5th, 10th, 15th, 20th and 25th laundering periods. The calculated F values of 3.75 for

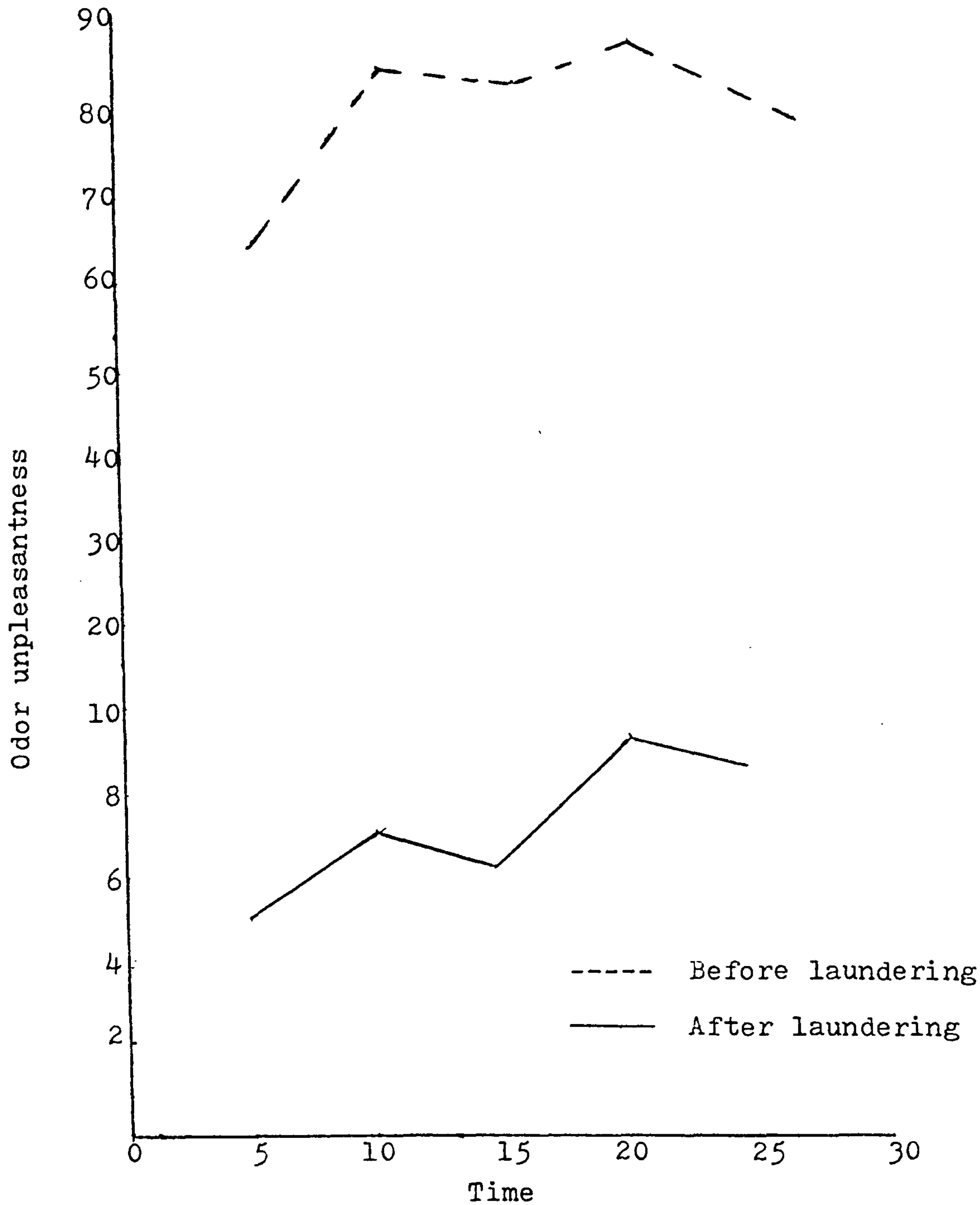


Figure 3. Mean scores for the unpleasantness of odor present in both sets of shirts before and after laundering

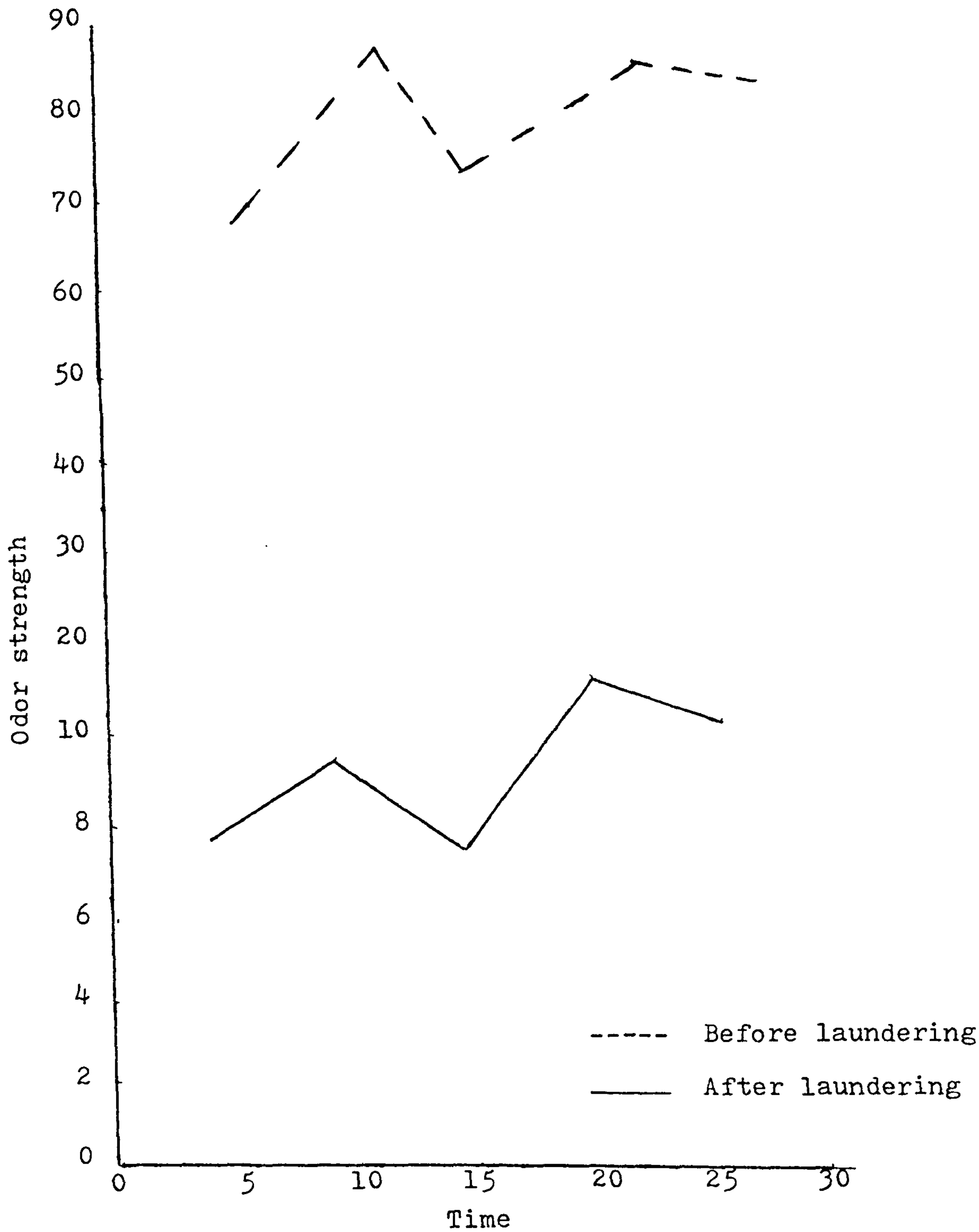


Figure 4. Mean scores for the strength of the odor present in both sets of shirts before and after laundering

strength and 3.76 for unpleasantness were significant at the .05% level. Comparison of the means indicated that there was no significant change in odor content from one period to another in each set of shirts; however, the odor present in the 100% polyester was significantly greater at the 20th and 25th launderings, respectively, than at the 5th laundering at the .05% level. The mean scores were tabulated and shown in Tables 1 and 2. No significant odor changes were observed in the 65/35% polyester/cotton blend. The greatest increase occurred between the 1st and 5th launderings. The increase between the 5th and 10th launderings was more gradual.

The calculated F value of 2.10 for interaction between time and composition was not significant at the .05% level, indicating that the amount of odor removed in each set was fairly constant over the time period. Hypothesis 1 was accepted for the 100% polyester.

Effect of Fiber Content on Odor Build-up

Tests were performed to test the hypothesis that the 65/35% polyester/cotton blend shirts will retain less odor than the 100% polyester shirts. The odor build-up of the two fiber contents was compared over the experimental period. The calculated F value of 4.39 showed that the 100% polyester accumulated a significantly greater amount of odor than the 65/35% polyester/cotton blend at the .05% level. The interaction between number of launderings and fiber content was

Table 1. Mean scores for the strength of odor present in both sets of shirts before and after laundering

	Before washing		After washing	
Time	100% polyester	65/35% polyester/ cotton	100% polyester	65/35% polyester/ cotton
5th	66.41	68.06	5.06	10.69
10th	90.42	85.40	8.56	10.51
15th	83.95	69.00	8.63	6.91
20th	91.94	79.29	10.61	13.33
25th	91.06	65.90	10.39	9.75

Table 2. Mean scores for the unpleasantness of odor present in both sets of shirts before and after laundering

	Before washing		After washing	
Time	100% polyester	65/35% polyester/ cotton	100% polyester	65/35% polyester/ cotton
5th	59.12	65.48	3.46	7.01
10th	87.03	81.02	6.52	7.59
15th	77.37	64.60	6.67	5.98
20th	87.96	75.15	7.66	9.99
25th	82.73	61.40	8.80	8.03

significant at the .05% level. The mean scores for the two sets of shirts for the before and after laundering evaluation are given in Tables 1 and 2. While the 100% polyester had more odor before laundering, it had a slightly lower value for the after laundry evaluation. Hypothesis 3 was accepted.

Effect of Deodorant on Odor Build-up

Table 3 gives the mean scores for unpleasantness for both male and female and Negroes and Caucasians in the deodorant and nondeodorant groups. The calculated F value of 21.30 was highly significant at the .05% level. Comparisons between the means for the two sexes showed that both the male and female in the deodorant group accumulated less odor than their counterparts in the nondeodorant group. Comparisons within the races also indicated that subjects wearing deodorant accumulated less odor than those subjects in the nondeodorant group. The calculated F value for the Negroes was 2.87 and for the Caucasians, 2.89. Both values were significant at the .05% level. The values for the sexes were 3.66 for the male subjects and 2.79 for the female subjects. Hypothesis 2 was accepted.

The mean scores for the strength of odor are given in Table 4. The F and t tests yielded results similar to the values for unpleasantness. The calculated F value of 13.91 showed that the odor of those subjects in the nondeodorant group was significantly stronger than the odor of those subjects in the deodorant group at the .05% level. The t tests

Table 3. Mean scores for the unpleasantness of the odor present in the shirts for the deodorant and non-deodorant groups from both sexes and racial groups

	Deodorant		Nondeodorant	
Race	Male	Female	Male	Female
Caucasian	38.77	28.04	53.95	49.85
Negroid	34.68	37.21	59.76	46.47
Overall mean	36.72	32.74	57.01	48.16

Table 4. Mean scores for the strength of the odor present in the shirts for the deodorant and nondeodorant groups for both sex and racial groups

	Deodorant		Nondeodorant	
Race	Male	Female	Male	Female
Caucasian	41.55	33.28	55.81	51.52
Negroid	38.17	42.48	63.19	49.29
Overall mean	39.86	38.00	59.69	50.40

indicated that the males and female subjects wearing deodorant had a milder odor than their counterparts in the nondeodorant group. The computed values were 3.69 for males and 2.81 for females and both were significant at the .05% level. The comparison between races also gave significant F values at the .05% level.

Tests were made to determine the effects of race and sex on odor build-up. The F tests yielded values of .51 and 1.0 for the strength of odor between the races and sexes, respectively. Both values were not significant. The values of .35 and 2.55 for unpleasantness were not significant. Hypotheses 4 and 5, that the garments worn by the female and Negro subjects will retain more odor than the garments worn by the male and Caucasian subjects, were rejected.

Effect of Deodorant on Strength Retention

The effect of deodorant on the loss of fabric strength was examined for both sets of shirts. The t tests between the means for the shirt tails and the means for the underarm areas indicated that there was no significant loss of strength due to perspiration at the .05% level, in both sets of shirts. The F tests showed no significant differences due to either sex or race. The interaction between sex and deodorant for the warp threads of the 65/35% polyester/cotton blend shirts yielded a significant F value of 11.08 at the .05% level. The mean scores are given in Table 5. While the scores for the nondeodorant male group indicated a loss of strength relative to the deodorant group, the female nondeodorant scores showed a slight gain in strength. Hypothesis 6 was rejected on the basis of the results.

Table 5. Mean breaking strength of the warp and filling yarns for the deodorant and nondeodorant groups wearing the 65/35% polyester/cotton blend shirts

	Warp		Filling	
Sex	Deodorant	Nondeodorant	Deodorant	Nondeodorant
Male	56.80	55.60	44.20	49.00
	52.60	34.00	33.00	52.20
Female	49.20	56.60	38.10	39.60
	53.80	57.60	33.70	28.60

Durable Press Performance

Figure 5 gives the durable press ratings of both sets of shirts over the experimental period. Analysis of variance showed a significant difference in the appearance of the shirts over a period of time. The computed F value of 101.0 was highly significant at the .05% level. There was a significant interaction between time and composition. While the 100% polyester decreased inversely with time, the ratings for the 65/35% polyester/cotton fluctuated. The data in Table 6 are graphed in Figure 5.

After the 5th laundering, a light colored line appeared in the middle of the back of the 65/35% polyester/cotton blend shirts for the female subjects. This line was found to correspond to the brazier line at the back and was the original

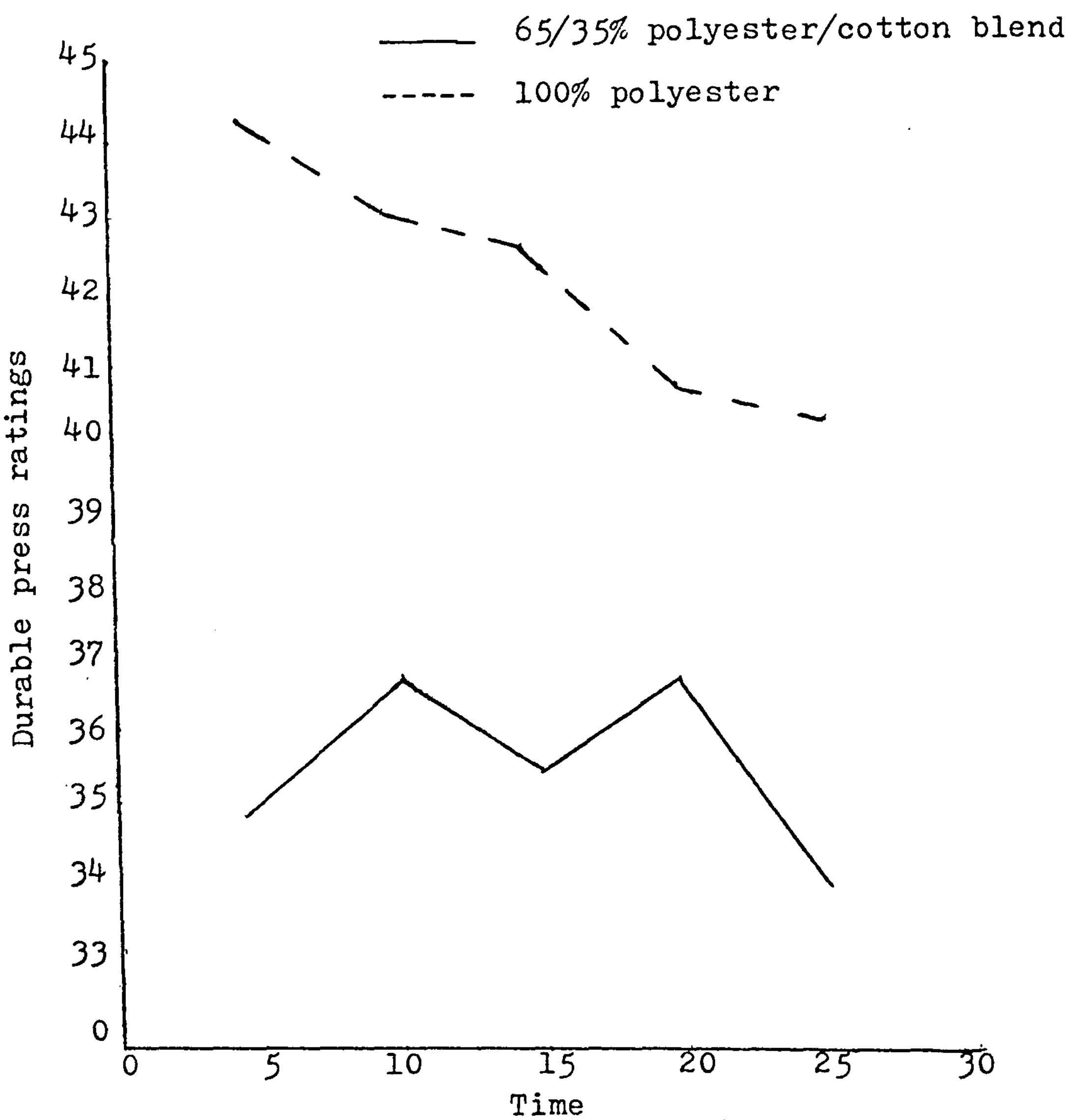


Figure 5. Graphical representation of Table 6

Table 6. Mean ratings for the permanent press performance of both sets of shirts over 25 laundering periods

Time	Polyester/cotton	100% polyester
5th	34.91	44.71
10th	36.42	43.00
15th	35.33	42.92
20th	36.25	40.91
25th	33.91	40.42

color of the shirts. The surrounding areas acquired a dark oily appearance. This became more prominent as the wear study progressed and spread to include the sleeve caps. The areas where the seams protected the garment from the body retained their original color. This peculiarity was not observed in the white shirts of the same fiber content for the female subjects nor was it noticed on the blend shirts worn by the male subjects. The t test indicated that the blend shirts lost a significant amount of their strength due to wearing and laundering while no significant loss was shown for the polyester shirts. Hypothesis 7 was accepted.

Analysis of Odor Compound

Analysis of the odor compound revealed that the alkaline extract of the substance which caused the odor could be evaporated at moderate temperatures and stored and on acidification the odor returns. On injection into the gas chromatograph faint odors suggestive of methyl or dimethyl sulfide were first smelled followed by the odors of burnt sugar and propionic acid. An odor characteristic of sweaty polyester fabric finally came out at about 150°C over an unusually long time; it was more intense than the other odors.

Gas chromatography of the decyl esters formed from the odor extracts gave many peaks, indicating the presence of a number of short chain fatty acids. Acetic and propionic acids were especially prominent.

When the odor was put on thin-layer plates of silica gel and developed with a solution of ethanol, chloroform, ammonium hydroxide and water (70:40:20:2) it was discovered that the odor moved about 40% of the distance up the plate. This was revealed by drying the plate and dropping spots of 1 N hydrochloric acid on the plate. When the acid was added to the right spot the odor was detected. It was also revealed by exposure to iodine vapors. After the iodine treatment, however, the odor was not released by hydrochloric acid except after subsequent treatment with stannous chloride. Hydrogen peroxide could also remove the odor.

The odor containing spot was extracted from thin-layer plates with 1 N hydrochloric acid and reacted with a saturated solution of 2,4-dinitrophenyl hydrazine in 1 N hydrochloric acid. A precipitate was formed whose spectrum was characteristic of a dicarbonyl compound (Earl Hammond, Department of Food

Technology, Iowa State University, Personal communication, 1974).

Effect of deodorant on color

There were no observed changes in color attributable to perspiration.

DISCUSSION

The deodorant, Right Guard, was chosen because it is the only product designed for both men and women (Carsch, 1969) and a 65/35% polyester/cotton because it was a proportion of fiber content commonly used for woven shirts.

An analysis of variance indicated that a significant amount of odor was retained in the shirts. This result is in keeping with the findings of other researchers. As shown in Figure 3, the increase was greatest for the 5th wash. The amount of odor rose from zero to 4.5 units for the after laundry evaluation. The increase from the 5th to 10th laundering was just one unit for the after wash evaluation and 20 for the before. In the remaining periods, the increase was even more gradual. Rounds et al. (1973) and Schott (1969) observed the same behavior in the oily soil retention pattern of polyester and polyester/cotton blend fabrics. They attributed it to the saturation of the oil sites on the fiber. An examination of the two fiber compositions showed that, while there was a steady increase in the amount of odor retained in the 100% polyester, the values for the 65/35% polyester/cotton blend fluctuated. The values given in Table 1 revealed that the after wash figures dropped at the 15th laundering, rose sharply at the 20th and dropped again. Huisman and Morris discovered that abraided durable press fabric had a higher initial value for soil retention than 100% polyester but it later acquired a lower value as the fabric disintegrated from abrasion. The polyester, which had a better resistance to abrasion, ended with a higher retention of soil. The pattern of the results as shown in Tables 1 and 2 appears to agree; however, it is doubtful whether the level of abrasion in an automatic home washer used in the experiment was high enough to justify the sudden drop from 10.6 to 6.91 and if the fibers were disintegrating they would not rise again in the 20th laundering period.

The interaction between composition and laundering period was significant. While the polyester had more odor before washing, it lost more in the laundering process. Brown et al. (1968) attributed this to the fiber and yarn structure. Polyester, being less permeable to air than the blend, provided conditions more conducive to odor formation; however, the smoother surface made it easier to loose the products of decomposition during laundering.

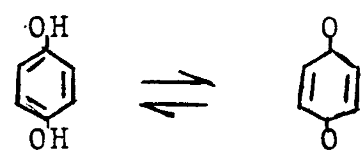
Analysis of variance revealed that those subjects wearing deodorant accumulated less odor in their garments than the subjects not wearing deodorant. While accepting hypothesis 3 for this study, a general conclusion cannot be drawn since deodorants differ in their active compound. Variations in the anti-microbial agent and propellant used can greatly alter the performance of the product.

The effect of sex on odor build-up was examined. Kuno (1934) stated that women were more odorous than men. The results of this study, however, indicated that there was no significant difference between the male and female subjects. The calculated F value 1.0 was not significant. The computed F values of 3.69 and 2.81 for differences between male and female deodorant and nondeodorant groups, respectively, seemed to point to the fact that there was a greater difference between the two male groups than there was between the two female groups.

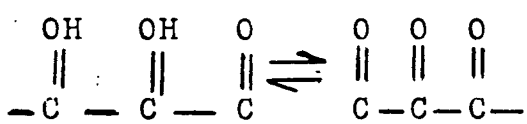
Tests were made to discover what racial differences there were in odor build-up. Kuno (1934) and McCord and Witheridge (1949) stated that Negroes were more odorous than Caucasians because they had a higher number of apocrine glands, while Fiedler (1969) attributed this difference to the larger sweat pores of Negroes which provided conditions conducive to rapid decomposition of sweat. The results of this study indicated that there was no significant difference between the Negroid and Caucasian subjects. The subjects were all sedentary graduate students living under similar environmental conditions. The computed F value of 0.51 was not significant. Kuno and McCord and Witheridge stated that diet made a difference in perspiration odor. Since the subjects were on American diets it could be that the difference observed by these earlier researchers was due to diet rather than some genetic characteristic.

The results of the study showed no loss of strength due to perspiration. No loss was expected for the 100% polyester, the fiber being highly resistant to acids and alkalis, especially in the weak concentrations found in perspiration. However, the blend was expected to show a decrease because of the cotton content. This lack of reaction could be attributed to the high polyester content, or the fact that the shirts were laundered daily rather than stored for some days then laundered as would be the case in most households. Both Barail (1947) and Barnes (1931) found that the aging of perspiration on fabric facilitated the decomposition of the fiber.

Two suggestions were put forward as to the nature of the compound from the above results: (1) A compound related to hydroquinine. Hydroquinine is reversibly oxidized to quinine. It is, however, not very odorous but a related compound might be. The odor compound, however, formed a salt which hydroquinine is not acid enough to form.



(a) Another possibility is a reductone



but the unoxidized form does not seem to react with phenylhydrazine so the keto group would have to be altered. An ascorbic acid-like molecule is possible.

This would account for the acidity of the odor (Earl Hammond, Department of Food Technology, Iowa State University, Personal communication, 1974).

SUMMARY

To determine the effect of deodorant on perspiration odor and strength retention of polyester and polyester/cotton blend fabrics the following objectives were established for the study:

1. To evaluate odor retention in fabrics after wearing and laundering.
2. To evaluate strength retention after wearing and laundering.
3. To determine colorfastness in specified areas of the garments.
4. To determine the durable press ratings of the garments.
5. To identify the odor causing compound.

The study was conducted using 100% polyester and a 65/35% polyester/cotton blend shirts worn by Caucasian and Negro subjects over a period of 45 days. Two subjects from each group acted as control by wearing the shirts without deodorant while the rest wore a deodorant designed for both males and females. The shirts were evaluated for odor retention before and after the 5th, 10th, 15th, 20th and 25th launderings by a panel of twelve untrained judges using a four point scales, one for strength and the other for unpleasantness. The garments were tested for color retention using the grey scale for color after the 25th laundering, and the Scott Tester was used to determine the loss of strength. A panel

of three trained judges was used to evaluate the durable press performance after the 5th, 10th, 15th, 20th and 25th launderings.

Data obtained from the objective evaluation revealed the following information:

1. That there was a build-up of odor in the 100% polyester shirts over 25 laundering periods.
2. That the use of deodorant reduced the build-up.
3. That there were no differences in odor build-up attributable to race.
4. That there were no differences in odor build-up attributable to sex.
5. That the 100% polyester is more likely to build up odor than the 65/35% polyester/cotton blend.

Data obtained from the objective evaluation of color and strength showed that:

1. There was no change in color that could be attributed to perspiration.
2. There was no difference in loss of strength between the shirts worn with deodorant and those worn without deodorant.
3. The 100% polyester shirts had a better appearance than the 65/35% polyester/cotton blend shirts.
4. The odor accumulated was not large enough to be picked up by the gas chromatography.

Since literature indicated that the human nose was more sensitive than most instruments used in odor measurement, more attention was given to subjective evaluation and the results seemed to confirm this. From the results of the study it can be concluded that Right Guard effectively checked the build up of perspiration on the lightweight polyester doubleknit garments, made from filament yarns. It is difficult to make a general statement about deodorants since they differ widely in their antibacterial properties and in the propellant used and these can actively affect the potency of the product. While it can be concluded that there is no racial difference in odor between the Negro and Caucasian under similar environmental conditions, the effect of diet needs to be investigated to find out if diet rather than some genetic characteristic was responsible for the differences observed by earlier researchers.

RECOMMENDATIONS FOR FURTHER STUDY

The problems that need to be given further attention are:

1. The choice of experimental period. The experiment needs to be carried out over a longer period of time and during the hot months of the year.
2. The effect of diet. The effect of diet on odor retention needs to be investigated.
3. Subjective evaluation. The scale needs to be refined and means of screening the judges for sensitivity should be explored.
4. The number of subjects used needs to be increased.
5. Aging of perspiration. The perspiration should be aged on the fabric so as to get a truer picture of its effects in a normal household situation.

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