Effects of Outdoor Drying on Cotton Fabrics with Special Reference to Solar Radiation

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Introduction

The service received from many cotton fabrics is affected by the way they are laundered. Drying is a part of the laundering; and, in Oklahoma, outdoor drying is a common practice. Outdoor drying means exposure to prevailing atmospheric conditions. These conditions vary considerably between different parts of the country. They also vary from hour to hour, day to day, and season to season within the same area.

A clear day with maximum sunlight is looked upon generally as a good "wash day". However, sunlight or solar radiation may affect fabrics unfavorably through fading of color, bleaching, loss of whiteness and reduction of strength. These in turn result in unsatisfactory appearance and reduced serviceability. The extent of the deterioration is affected by the total irradiation, by the relative proportion of the different wave lengths of light, by the presence of agents such as smoke, dust, oxygen, ozone and moisture in the atmosphere, and by wind and temperature changes.[1]

This bulletin reports the effects of outdoor drying—with known amounts of solar radiation—on fading, bleaching, whiteness and breaking strength of three cotton percales at different hours of the day and seasons of the year.

The solar radiation reaching the earth's surface at a specific location is measured in energy units of gm cal per sq cm. Data on radiation were obtained from the Department of Physics and Meteorology at Oklahoma State University, Stillwater.[2] Stillwater is located in north central Oklahoma. It has no local conditions which might provide abnormal amounts of oxidizable gases or smoke in the atmosphere.

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[1]National Research Council. Prevention of Deterioration Center. *Deterioration of Materials: Causes and Preventive Techniques.* Reinhold, New York City, pp. 88-91, 465-466. 1954.

[2]The department is an official recording station of solar radiation for the United States Weather Bureau.

Materials, Methods, and Experimental Conditions

The Fabrics

The three percale fabrics selected for study were unbleached, bleached (white), and dyed (pink).[3] The percales were the same original fabric, an 80-square percale. In order to reduce variations, it was desirable to use fabrics which were alike except for differences due to bleaching and dyeing. To produce the bleached or white percale, unbleached fabric was run through a continuous bleaching operation in which an acid treatment, a caustic soda treatment, and a final hydrogen peroxide treatment were applied to the cloth. The dyed fabric was subjected to the same bleaching treatment as the white cloth and was then dyed pink with pigment colors. Fixation of the pigment was obtained by use of a cured resin.[4]

Fabric Measurements

The fabrics were cut into pieces and hemmed to yield swatches approximately 14" x 14".

For each of the three 2-hour exposures and seven seasonal periods, five swatches of each fabric were used for measuring the effect of the exposure on reflectance (retention of whiteness, bleaching and fading), breaking strength and number of yarns per inch. Each swatch provided five measurements of reflectance, ten each of warp and filling breaking strength, and five each of warp and filling count.

Reflectance was measured with a Gardner Automatic Multipurpose Reflectometer, and the results reported in terms of relative whiteness, bleaching and fading of the fabrics receiving the different exposures.

Breaking strength was measured by the strip method by use of a Scott Tester.

Fabric Treatments

Prior to each exposure, the samples to be tested were covered with clear water at 38 to 40 degrees Centigrade and left in the water for 10 minutes to become well saturated. They were then squeezed by hand and hung on outdoor lines.

The lines on which the fabrics were hung were in an east--west direction, fully exposed to sunlight the entire day. They were 63 inches from

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[3]The fabrics were donated by Pacific Mills, Lyman, South Carolina.

[4]Correspondence dated June 1, 1955, from Pacific Mills, Lyman, South Carolina.

the ground and 30 inches apart. The fabrics were hung on the lines as single thicknesses of cloth, and, therefore, dried more quickly than most articles of cotton clothing would dry.

Exposures for the drying were varied by time of day and season of year. A total of 21 exposure treatments was used, seven different periods of the year, and three times of day for each of the seven periods. The seven periods were:

Midsummer (June 18 to July 27, 1955)
Late summer (July 28 to September 21, 1955)
Fall (September 22 to November 18, 1955)
Winter (November 19, 1955 to March 20, 1956)
Full summer (June 18 to September 21, 1955; i.e., both the "midsummer" and "late summer" periods)
Fall and winter (September 22, 1955 to March 20, 1956)
Total time (June 18, 1955 to March 20, 1956; i.e., the entire period of the experiment)

For each of these periods, there were three sets of samples. One set was exposed from 9 to 11 a.m., the second from 11 a.m. to 1 p.m., and the third from 1 to 3 p.m.

The swatches were hung on the line the first 2-hour exposure only on days which were clear at the 9 o'clock hour or predicted to be clear.[5] Swatches were not hung on the line at hours when the temperature was below freezing.

Any time the fabrics were removed from the lines because of cloudiness, they were re-hung the next clear day at the same hour they were taken off the line to complete the 2-hour exposure. At these times, the fabrics were re-hung on the line dry.

Radiation

The solar radiation to which the fabrics were subjected at the different hours, 9 to 11, 11 to 1, and 1 to 3 during the 20 days (40 hours) of the first period (midsummer), was used as a base figure for exposure in all the other periods.

For the fabrics to be exposed at all periods to the same amount of solar radiation as that of the base figures, extra hours of exposure were necessary at most of the seasonal periods. For these additional hours of

[5]Weather forecasts were obtained from the Department of Physics and Meteorology.

exposure, the dry fabrics were hung on the line intermittently with the exposures when the fabrics were hung on the line wet.

The amount of radiation to which the fabrics were subjected at the different seasonal periods could not be exactly duplicated because radiation could not be known until after the fabrics were exposed. The amount of solar radiation to which the fabrics were subjected at each period and in each season is shown in Table 1.

In considering the effect of outdoor exposure of fabrics where the time of exposure may be relatively short, as in drying clothes, data on solar radiation for a given hour is important. Total radiation for a day does not indicate whether low radiation occurred in certain hours only or was continuous throughout the day.

Of the conditions to which the fabrics were exposed, only total radiation was known. The fabrics which required more hours of exposure at some seasons than at others to receive equivalent amounts of irradiation were, of course, subjected to the other outdoor conditions prevailing at the time of the additional hours of exposure.

The longer time, nearly three months, required to complete the exposures during the winter period was due partly to low temperatures at the 9 o'clock hour. During November, December, January and February, the temperature fell to 32° or lower eighty days (See Table 2). The late summer period, the time between July 28 and September 21, included a month in which no fabrics were exposed.

Comparison of four months in 1955 and in 1956—One would need to compare data on solar radiation over a long period of time to find how much alike a season is from year to year, but Figures 1 and 2 show that the average hourly solar radiation from 8 a.m. to 4 p.m. for the same four months in 1955 and in 1956 varied more between months in 1955 than in 1956. The average radiation per hour was nearly the same for the months June through September in 1956. For the same months in 1955, the radiation at midday hours was lower than for the same period in 1956, and radiation in September was considerably less than for the other three months in 1955.

Temperature and Precipitation—Data on temperature and precipitation at Stillwater, Oklahoma, for June, 1955, through March, 1956, (Table 2) show rainfall to be less than one inch per month for five months and more than three inches for only two of the ten months.[6]

[6]United States Department of Commerce. Weather Bureau. Climatological Data. Oklahoma. Vol. LXIV. No. 6-12, 1955, Vol. LXV, No. 1-3, 6-9, 1956.

Table 1.—Solar radiation in gm cal per sq cm to which the cotton fabrics were exposed at different hours of the day and seasons of the year from June, 1955, through March, 1956. (Radiation measurements were made on a horizontal surface.)

Seasonal Period of Exposure	Calendar Period of Exposure	Radiation in gm cal per sq cm								
		9 a.m. to 11 a.m.			11 a.m. to 1 p.m.			1 p.m. to 3 p.m.		
		Total rad.	Total hours	Ave. per hr.	Total rad.	Total hours	Ave. per hr.	Total rad.	Total hours	Ave. per hr.
Midsummer	June-July	2208	40	55.2	3090	40	77.3	3262	40	81.6
Late Summer	July-Sept.	2190	39	56.1	3080	43	71.6	3142	45	69.8
Fall	Sept.-Nov.	2203	48	45.9	3097	50	61.9	3231	58	55.7
Winter	Nov.-Mar.	2196	67	32.8	3145	64	49.1	3296	69	47.8
Full Summer	June-Sept.	4398	79	55.8	6170	83	74.3	6404	85	75.3
Fall & Winter	Sept.-Mar.	4399	115	38.2	6243	114	54.8	6528	127	51.4
Total time	June-Mar.	8797	194	45.3	12413	197	63.0	12932	212	61.0

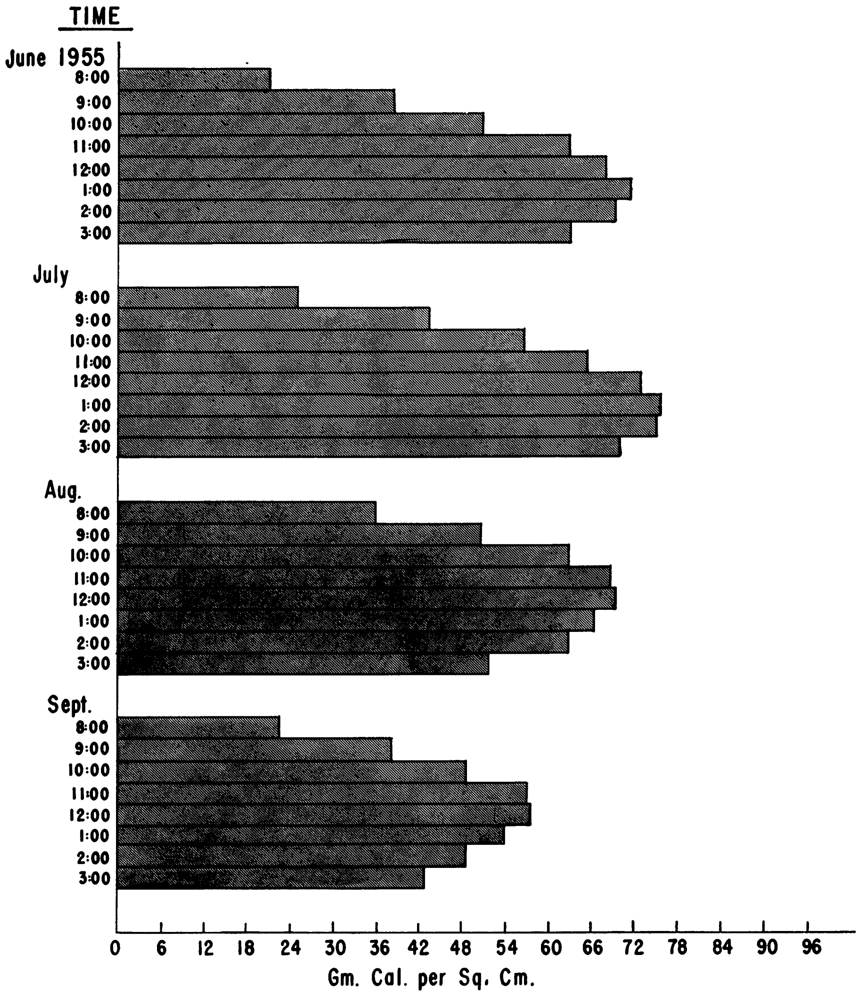

Figure 1. Solar radiation at Stillwater, Oklahoma, June-September, 1955, average per hour 8 a.m. to 4 p.m.

The maximum temperature was 90° or above most of July and August and about half of September. For November, December, January and February, the total precipitation was 1.59 inches. However, the number of days within each of the four months in which radiation at the 9 o'clock hour was less than the average totaled 45. There can be considerable cloudiness and therefore less solar radiation without precipitation.

During the ten-month period from June through March, extreme cloudiness occurred throughout the day as indicated by recorded radia-

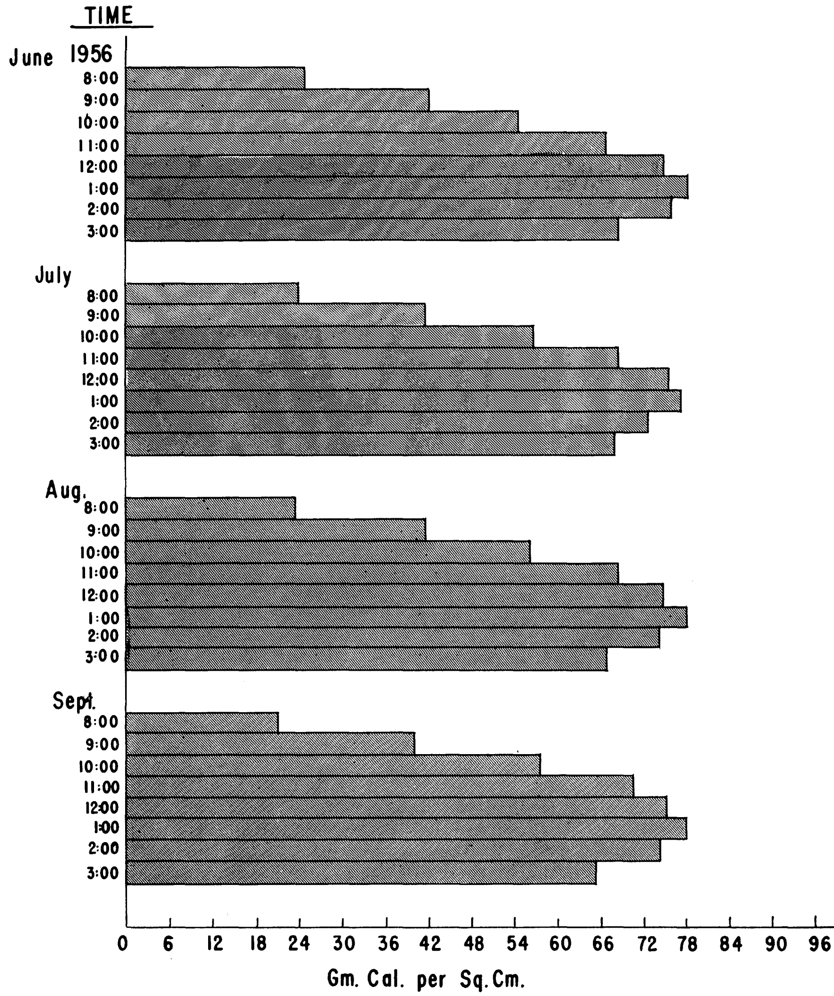

Figure 2. Solar radiation at Stillwater, Oklahoma, June-September, 1956, average per hour 8 a.m. to 4 p.m.

tion from 8 a.m. to 4 p.m. only a few days from June 1 until the latter part of September. During November, December, January, and February radiation was low for every hour of the day and less than a daily total of 100 gm cal per sq cm for 21 days.

During the summer months in Oklahoma, the maximum radiation and maximum temperature are not likely to occur at the same hours. Maximum temperature is usually between two and three o'clock but the peak solar radiation is reached at an earlier hour.

Table 2.—Temperature and precipitation, Stillwater, Oklahoma, June, 1955—March, 1956, and June, 1956—September, 1956*

		Temperatures								Precipitation
Year	Month	Max. Deg. F.	Min. Deg. F.	Max. Av.	Min. Av.	Av.	No. days 90° or above	No. days max. temp. 32° or below	No days min. temp. 32° or below	Total in Inches
1955	June	93	50	85.1	63.4	74.3	8	0	0	3.42
	July	102	69	96.1	73.3	84.7	28	0	0	1.36
	Aug.	101	58	94.9	69.3	82.1	28	0	0	2.44
	Sept.	100	54	90.1	65.2	77.7	17	0	0	1.16
	Oct.	89	30	76.6	49.8	63.2	0	0	1	5.03
	Nov.	77	14	61.3	33.1	47.2	0	0	15	0.00
	Dec.	84	12	51.5	26.5	39.0	0	0	23	0.18
1956	Jan.	72	7	48.3	25.3	36.8	0	3	24	0.43
	Feb.	82	11	54.3	30.5	42.4	0	3	18	0.98
	Mar.	87	17	67.9	38.9	53.4	0	0	10	0.59
1956	June	103	52	91.5	67.7	79.6	20	0	0	1.79
	July	105	63	99.1	72.0	85.6	29	0	0	1.09
	Aug.				NO DATA					
	Sept.	103	49	95.6	62.8	79.2	24	0	0	0.20

*U. S. Dept. of Commerce. Weather Bureau. Climatological Data. Oklahoma. Vol. LXIV, No. 6-12, 1955, Vol. LXV, No. 1-3, 6-9, 1956. (Data were taken from Table II in each issue.)

Results

Solar Radiation

Irradiation of the fabrics was greater during the 1 to 3 hours than during the 11 to 1 hours for the 40 hours of midsummer exposure, but the main difference was between the 9 to 11 hours and the other two periods. The radiation for the 9 to 11 hours was much lower, as shown in Table 1. Temperature and rate of drying would be among the other differences between conditions at the 9 to 11 hours and the later hours in the day.

Except for the 9 to 11 exposure during the late summer season, the number of hours of exposure for each of three periods, 9 to 11, 11 to 1, and 1 to 3 had to be increased over the 20 days or 40 hours of exposure to provide equivalent amounts of irradiation at the other seasons (See Table 1). As to be expected, the greatest difference in radiation occurred between the midsummer and the winter seasons. The difference in radiation between these two seasons was least for the 11 to 1 hours. For the fabrics to receive approximately the same amount of irradiation in winter as in summer, the exposure had to be increased 67½ percent (27 hours) for the 9 to 11 hours, 60 percent (24 hours) for the 11 to 1 hours, and 72½ percent (29 hours) for the 1 to 3 hours.

Although the amount of irradiation which the fabrics received in midsummer at the 1 to 3 period was higher than for the other periods, the radiation at the 1 to 3 period dropped more than the other two periods at the late summer season. The total radiation per hour from 9 to 3 was highest during the hours 1 and 2 in June and July and during the hours 11 and 12 in August and September.

Maximum radiation occurred during the 1 o'clock hour more days of the month from June, 1955, through March, 1956, than for any other hour. On days in which there was intermittent cloudiness, the cloudiness occurred more often in the morning or afternoon hours than at midday hours.

The average radiation per hour from 8 to 4 and the average per day for ten months, from June, 1955, through March, 1956, are shown in Table 3. For the same period of time, radiation per hour and total for one day of maximum radiation near the middle of the month were much higher than the average (See Table 4).

Since the days for exposure of the fabrics were selected as "clear days" the radiation would undoubtedly be higher than that for the same hours averaged over an equal number of consecutive days.

Table 3.—Solar radiation for the 10 months, June, 1955, through March, 1956, during which fabrics were exposed; average per hour 8 to 4 and total per day.

	Month	Radiation in gm cal per sq cm average per hour 8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	Total 8-hour day
1955	June	20.8	38.0	50.7	62.7	67.7	71.3	69.2	63.0	443.4
	July	24.4	43.2	56.3	64.9	73.2	75.5	75.3	70.4	483.2
	Aug.	35.3	50.5	62.8	68.0	69.5	66.4	62.5	51.8	466.8
	Sept.	22.6	38.0	48.6	57.1	57.6	54.1	48.3	40.1	366.4
	Oct.	17.0	33.0	45.9	54.0	57.1	57.4	49.6	38.2	352.2
	Nov.	17.8	31.2	41.6	48.2	50.9	44.6	36.5	23.3	294.1
	Dec.	14.5	27.0	36.0	39.7	28.0	31.4	21.7	10.5	218.8
1956	Jan.	1.3	9.2	19.7	28.9	33.7	35.8	32.2	24.0	184.8
	Feb.	2.2	11.4	22.2	32.6	38.7	43.0	46.8	40.6	237.5
	Mar.	8.0	23.4	40.7	53.5	61.4	65.6	64.8	58.7	376.1

Table 4.—Solar radiation in gm cal per sq cm per hour from 8 to 4 for the day of highest radiation between the 12th and 16th days of the month for a period of 10 months June, 1955, through March, 1956.

	Date	Radiation in gm cal per sq cm per hour 8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	Total 8-hour day
1955	June 12	28.5	52.2	61.5	76.2	83.1	85.2	84.9	78.3	549.9
	July 15	28.1	50.4	63.6	74.1	82.2	88.5	84.6	73.8	545.3
	Aug. 14	45.0	61.5	72.0	80.1	82 8	82.2	74.7	63.6	561.9
	Sept. 13	27.0	45.9	60.6	68.7	72.6	71.7	64.8	54.9	466.2
	Oct. 14	21.6	41.4	57.3	66.6	70.2	68.1	60.6	49 5	435 3
	Nov. 16	17.1	30.9	46.2	57.0	61.2	59.1	50.7	37.2	359.4
	Dec. 15	19.8	34.5	45.0	50.1	49.5	43.5	31.5	15.0	288.9
1956	Jan. 12	4.2	21.9	38.4	45.6	51.3	52.2	47.1	36.3	297.0
	Feb. 13	1.5	13.5	31.5	49.2	57.3	57.0	62.7	56.7	329.4
	Mar. 16	14.4	33.9	52.8	66.6	73.8	77.7	74.4	66.9	460.5

Exposure of the fabrics at the different hours of the day during the four seasons, midsummer (June-July), late summer (July-September) fall (September-November), and winter (November-March), in which the amount of irradiation of fabrics was comparable, resulted in differences between seasons and between fabrics. In addition to radiation there are other conditions, as mentioned previously, which affect color changes and deterioration of cotton fabrics in outdoor exposure.

Whiteness, Bleaching, and Fading

During the four seasons in which the fabrics received a similar amount of irradiation, the most bleaching of unbleached percale occurred in the midsummer season and least bleaching in the fall season The white percale retained best whiteness in the late summer season of exposure. There was little difference in the amount of fading of the colored percale when dried during the four seasons. The dyed percale had good fastness of color to sunlight.

Bleaching and fading during the full summer season were greater than for the fall and winter season. Whiteness was better in the full summer season than in the fall and winter season.

Most fading occurred over the total period of exposure from June to March, but even then, the pink percale was not badly faded. The most bleaching and best whiteness might be expected over the total exposure also, but such was not the case. Probably the cause, in part, was some accumulation of dust in the swatches of cloth which were hung on the line for the longer periods of time. This condition may also have had a minor effect on the results of the full summer and the fall and winter exposures. Although fading and bleaching may increase as the fabric is subjected to additional irradiation, the change may not be proportional to the increase in exposure. Conditions which produce the most bleaching may not produce the best whiteness.

Irradiation of the three percales at different hours of the days resulted in some differences in bleaching, whiteness and fading. For the three 2-hour periods, the drying at the 11 to 1 hours resulted in the best whiteness and the most bleaching and fading of color. The retention of whiteness was equally good in the drying period 9 to 11 and 1 to 3. Least bleaching of the unbleached percale occurred in the 1 to 3 period, but the least fading of color occurred in the 9 to 11 hours. Since solar radiation was greater for the 1 to 3 hours, less bleaching but not less fading at that time may be attributed to the effects of differences in the radiation and other conditions in the exposure and drying at the 9 to 11 and 1 to 3 hours on the two fabrics.

In the midsummer season (June 18 to July 27), bleaching was least for the 1 to 3 hours and greatest at the 9 to 11 hours. The time of day of exposure made no difference in fading or retention of whiteness.

During the late summer season (July 28 to September 21) the amount of bleaching was least during the 1 to 3 hours and no different for the other two periods. Poorest whiteness resulted in the 1 to 3 exposure and most loss of color in the 11 to 1 period.

In the fall season, the most bleaching and best retention of whiteness occurred in the 11 to 1 exposure with no difference in the other periods. Least fading occurred in the 9 to 11 exposure.

In the winter season, there was least bleaching in the 1 to 3 exposure with no difference between the other periods. There was no difference in whiteness of the percale dried at the three different periods. Fading of color was less for the 9 to 11 exposure than for the 11 to 1 period, but neither of these periods differed significantly from the 1 to 3 period in amount of fading produced in the fabric.

In the full summer season, the amount of bleaching was least in the fabric exposed during the 1 to 3 period but was not different for the other hours. Least fading occurred in the 9 to 11 period. The whiteness was best in the 11 to 1 exposure and poorest in the 1 to 3 exposure. In the fall and winter season, bleaching was less from 1 to 3 than from 11 to 1, but there was no significant difference between results for the 1 to 3 and 9 to 11 exposure. Most fading occurred in the 1 to 3 period. Whiteness was not different for any hour of the exposure.

Yarns per Inch

A measure of the number of yarns per inch was made primarily to get information that would aid in interpreting results on breaking strength. It was expected that the count in the unbleached percale would increase in both the warp and filling because of the usual shrinkage in unfinished fabrics. The number of yarns per inch changed in the other two percales, also. The count increased in the filling direction in the white percale. In the pink percale, the count increased in the filling but decreased in the warp.

Breaking Strength

When a fabric shrinks or stretches in laundering so that the number of yarns to the inch is changed in the fabric, the strength will likely be different from that of the new fabric. In order to compare the strength of fabric in which the count has changed, it is often desirable to base the comparison on yarn rather than fabric strength. However, the individual yarns are not identical with those in the new fabric, for shrinkage has caused a change in them. From the standpoint of wear or durability of the fabric, it is strength of the fabric which is most important. In this investigation, length of exposure was insufficient to show the differences in strength which would be expected over longer exposures than the 40 hours of irradiation of the fabrics in midsummer.

Comparison of Fabrics—The retention of strength was better in the white and pink percales than in the unbleached. Of the white and pink percales, retention of strength was better in the white than in the pink.

Comparison of Seasons—The retention of strength warpwise was better in all fabrics during the fall season of exposure than for the other seasons of corresponding amounts of irradiation of the fabrics and lowest in the winter season. However, there was only a small difference in strength between the fall and late summer seasons. The retention of strength fillingwise was better in the unbleached percale in the fall season of exposure, but for the other two percales, retention of filling strength was not better at any one season of exposure.

In a comparison of the full summer and the fall and winter exposures, the warp strength of all percales was reduced more in the fall and winter season. The filling strength was reduced more in the full summer season except in the pink percale in which there was no difference in results for the two periods.

The unbleached percale was reduced in strength most in the total exposure, but the difference in loss of strength for the white and pink percales for the total exposure and that for the winter and fall season was not significant.

Comparison of Hours of Exposure—For the three 2-hour periods of outdoor drying, the unbleached percale loss of warp strength at the 9 to 11 hours was less but not significantly so from the other periods For the same exposures, the loss of strength warpwise in the white percale was less at the 9 to 11 hours than at the 1 to 3 hours. There was no difference in loss of warp strength of the dyed percale at the different 2-hour exposures. None of the percales showed any difference in filling strength for the three 2-hour periods of exposure.

In the midsummer season, there was no difference in the loss of warp strength of any of the percales as a result of the hour of exposure

In the white and unbleached percales the filling strength did not differ with hours of exposure, but in the pink percale loss of strength was greater in the 9 to 11 exposure than the 11 to 1 exposure.

During the late summer season, the time of day of exposure produced no difference in warp strength of the white percale. In the unbleached percale, loss of warp strength was greatest at the 11 to 1 hours. In the pink percale, greater loss of strength occurred at the 11 to 1 exposure than at the 9 to 11 exposure, but the difference between these exposures and the 1 to 3 hours was not important. There was no difference in strength fillingwise as a result of the hours of exposure.

In the fall season, the hours of exposure had no different effect on warp strength of the unbleached and pink percales. In the white percale, loss of strength was greater at the 1 to 3 than at the 9 to 11 exposure. The filling strength did not vary with hour of exposure.

In the winter season, the strength was not different for any fabrics, warp or filling, due to hours of exposure.

In the full summer season, the hour of exposure had no different effect on the unbleached and pink percales, but the loss of strength of white percale differed. Warp strength loss was greatest at the 11 to 1 hours. Filling strength loss was greater at 11 to 1 than at 1 to 3.

For the fall and winter season, loss of warp strength in the unbleached percale was less for the 9 to 11 exposure, and in the pink percale loss was lower at 9 to 11 than at 1 to 3. No difference was found in the warp strength of the white percale or in the filling of any of the fabrics.

For the total time from June to March, the hour of exposure made no difference in loss of warp strength in the unbleached and pink percales. In the white percale, loss of strength was greatest at the 1 to 3 hours. The filling strength did not vary in any of the fabrics exposed at the different 2-hour periods.

Throughout the various seasons, a difference in breaking strength due to hour of exposure was found less often in the filling than in the warp of the fabrics.

Summary

Percale fabrics, unbleached, white, and pigment dyed, all the same original fabric differing only because of the finishing, were dried on

outdoor lines at different hours of the day and seasons of the year. The purpose was to find how the exposure affected the reflectance as a measure of bleaching, whiteness and fading and the breaking strength.

The hours of exposure were: 9 to 11, 11 to 1, and 1 to 3. The seasons were: midsummer (June 18-July 27, 1955), late summer (July 28-September 21, 1955), fall (September 22-November 18, 1955), winter (November 19, 1955-March 20, 1956), full summer (June 18- September 21, 1955), fall and winter (September 22, 1955-March 20, 1956) and total time (June 18, 1955-March 20, 1956).

Among the conditions which affect the appearance and the deterioration of cotton fabric in outdoor drying is that of sunlight. In this investigation, the solar radiation in gm cal per sq cm at this location (Stillwater, Oklahoma) was known for each hour (9 to 3) from June 18, 1955, to March 20, 1956.

During the first season (midsummer) the percales were exposed in the outdoor drying at the three 2-hour periods for 20 days or 40 hours. The units of solar radiation recorded for those hours were used as base figures for exposures in all other seasons.

The amount of solar radiation to which the fabrics were exposed at the three 2-hour periods was similar for the 11 to 1 and 1 to 3 hours but was considerably less for the 9 to 11 hours. The difference in amount of radiation from midsummer season to winter season was greatest for the 1 to 3 hours and least for the 11 to 1 hours. For the fabrics to receive equivalent amounts of irradiation, the exposure in winter had to be increased 27 hours for the 9 to 11 hours, 24 hours for the 11 to 1 hours and 29 hours for the 1 to 3 hours.

In bleaching, whiteness and fading at different seasons, most bleaching occurred in the midsummer season, and best whiteness in the late summer season. Least bleaching occured in the fall season. Season of exposure had little effect on fading. The pigment dyed (pink) percale had good fastness of color to sunlight.

In bleaching, whiteness and fading at the 2-hour exposures, most bleaching, best whitness and most fading occurred in the 11 to 1 exposure. Whiteness was equally good in the period 9 to 11 and 1 to 3. Least bleaching occurred in the 1 to 3 period and least fading in the 9 to 11 hours. The effects of the hour of exposure on bleaching, whiteness, and fading were not the same at each of the three 2-hour periods for all seasons.

The number of yarns per inch changed in all of the fabrics due to shrinkage. This change, of course, had some effect on breaking strength of the exposed fabrics as compared with the new fabrics.

The unbleached percale had lower retention of strength than the other percales. The retention of warp strength of the percales was somewhat better in the fall season than in the other three seasons of comparable irradiation and lower in the winter season of exposure. The retention of filling strength was better in the fall season in the unbleached percale, but no one of the four seasons was distinctly better for retention of filling strength in the other two percales.

When all seasons were considered, the hour of exposure had no different effect on warp strength in the pink percale. The retention of warp strength in the unbleached percale was somewhat better for the 9 to 11 period. The retention of warp strength in the white percale was better at 9 to 11 than at 1 to 3. The hour of exposure produced no difference in retention of filling strength in the percales.