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Decay of Cotton Fibres and Fabrics by Fungi During Godown Storage and Effect of Environmental Factors

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ABSTRACT

Stored cotton and fabrics show distinct signs of fungal decay in their colour, feel and strength besides other physico-chemical and biological characteristics. Fabrics show maximum loss in tensile strength during soil contact storage. The moisture content, and chemical constitution of cotton alongwith storage conditions are directly correlated with the intensity of decay. Maximum loss of strength of cotton is evident at 30-35°C temperature and 90-95 per cent RH. The fungi attacking cotton during storage are mesophilic Deuteromycetes.

1. INTRODUCTION

The history of cotton textiles is as old as human civilization itself. Initially used for protection against nature, cotton textiles are required increasingly to satisfy man's aesmentation in his apparel and surroundings. Microbiological decay manifests in both raw and manufactured cotton in tropical areas during transit and storage. Under hot and humid storage conditions, fungi cause widespread cellulolytic activity and are mainly responsible for extensive and intensive damage to cotton and fabrics in tropics. But the information available on the mechanism of such decay is non specific and the mode of action of fungi on cotton is still not fully understood. For successful rot proofing of cotton textiles, therefore, and to increase its use on global scale, it is necessary to accumulate information on causative organisms in different hemispheres and latitude. Betrabet[1] reported fungi associated with degradation of cotton cellulose in humid belt near sea coast. Present attempt is made to investigate the deterioration of cotton and cotton fabrics during storage in godowns, the causal organisms and the effect of environmental factors on decay of cotton particularly in northern part of India.

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Cotton varieties	Place of collection	Place of growth	Season of storage	Colour	Feel	Bundle strength (tenacity) 0" gauge g/t	Moisture content (%)
Medium staple (20–21.5 mm)							
J34 RG	Dehradun	Punjab	1984-85	Dull white	Soft	29.96	7.5
J34 SG	Allahabad (Naini)	Punjab	1979-80	Dirty yellow	Coarse	22.49	6.6
Kalagin	Lucknow	Gujrat	1984-85	White	Coarse	35.02	9.3
Pakistan SG	Kanpur	Pakistan	1979-80	Dirty	Soft	29.50	13.2
V797	Rampur	Gujrat	1979-80	Yellowish	Coarse spotted	20.04	6.4
Wagad	Rampur	Gujrat	1981-82	Dull white	Rough	29.97	12.5
Short staple (19 mm and below)							
Khandwa-X-1	Kanpur	M.P.	1983-84	Dull white	Soft	29.30	0.4
CD at 5% level of probability						6.77	0.59

The per cent mature and immature fibres varied in the varieties of cotton taken under investigation, however the limits between the two groups are quite arbitrary. It was noticed that samples chosen, besides having wide range of fibre maturity, also represented the range of cotton cultivated in India from the point of view of the place of growth. The maturity ranged between 33.3-86.6 per cent. The alkali swelling value of different cotton varieties ranged between 4.762-13.104 micron indicating wide range of microbial decay (Table 2). The value of Congo red was also found higher in the cotton samples showing higher alkali swelling values. The fungal count per gram raw cotton ranged from 100 in case of variety F 414 SG which was clean to 3200 in A 51-9 which was very dirty. White and clean cotton had low fungal count than dull white dirty and spotted cotton.

Cotton fabric samples of in-service and outdoor exposed/stored conditions were yellowish to dirty with green, red, yellow, brown and black mildew spots, which on incubation yielded number of fungal species. In soil-contact stored samples perithecia-like bodies were well marked in few cases. The data of retained tensile strength of the fabrics were statistically analysed and the variation due to fabrics were found to be highly significant. The maximum tensile strength of the fabrics was marked during in-service (user) conditions followed by outdoor exposure and stored conditions.

4. DECAY OF COTTON AND FABRICS DURING STORAGE

The cotton varieties exhibited different rate of deterioration due to varied ability of fungi to attack cotton. The variation in chemical constitution of cotton is another reason for their varied susceptibility to fungal attack. Maximum decay in bundle strength (tenacity) of cotton was observed in AKH_4–AK_0 stored for nearly six years. The tenacity of cotton was found directly correlated with the duration of storage. No relation could be however established between the appearence of cotton and loss in its tenacity (Table 3). The variation in rate of decay of cotton fabrics during storage conditions was due to variation in their physical characteristics such as grey and

Table 2. Microscopic and biological characteristics of cotton stored in North India (mean values)

Cotton varieties	Microscopical characteristics					Biological characteristics
	Maturity per cent		Maturity ratio	Alkali swelling value (micron)	Congo red value (%)	Fungal count $\times 10^2$/g cotton
	Mature	Immature				
H_4 Bhikagaon	76.6	23.4	0.966	11.544	23.3	5.6
H_4 Burwaha	46.6	53.4	0.666	7.904	13.3	12.3
H_4 Dhamnood	60.0	40.0	0.800	8.944	23.3	9.6
H_4 Khirkya	66.6	33.4	0.866	6.441	10.0	3.3
H_4 Sendhwa	73.3	26.7	0.933	6.656	10.0	6.0
H_4 Wardha	66.6	33.4	0.866	7.065	16.6	2.0
DCH-31	86.6	13.4	1.066	7.065	10.0	7.6
DCH-32	43.3	56.7	0.633	7.260	10.0	10.3
MCU-5	70.0	30.0	0.900	4.992	6.6	2.66
MCU-11	63.3	36.7	0.833	7.169	13.3	3.0
S-4	43.4	56.7	0.633	7.072	13.3	1.66
S-6	70.0	30.0	0.900	6.126	6.6	5.00
1007	60.0	40.0	0.800	8.112	16.6	12.3
F414 RG	73.3	26.7	0.933	8.840	20.0	1.33
F414 SG	66.6	33.4	0.866	6.649	10.0	1.00
H777 SG	60.0	40.0	0.800	6.864	10.0	3.0
170-CO_2	43.3	56.7	0.633	9.048	20.0	14.0
A51-9	66.6	33.4	0.866	7.800	10 0	32.0
Ageti SG	46.6	53.4	0.666	8.008	16.6	7.3
AKH$_4$-AKO	63.3	36.7	0.833	12.168	73.3	7.6
G11	56.6	43.4	0.766	13.104	23.3	5.6
Y-1	50.0	50.0	0.700	7.052	13.3	5.6
Y-2	33.3	66.7	0.533	8.945	16.6	5.33
J-34 RG	76.6	23.4	0.966	7.270	10.0	12.3
J-34 SG	80.0	20.0	1.000	7.480	10.0	21.6
Kalagin	70.0	30.0	0.900	7.808	13.3	8.6
Pakistan SG	50.0	50.0	0.700	10.298	30.0	13.0
V797	76.6	23.4	0.966	6.200	10.0	15.6
Wagad	66.6	34.4	0.866	9.776	20.0	5.6
Khardwa X-1	56.6	43.4	0.766	4.762	6.6	12.6
CD at 5% of P	13.7			0.72	7.19	4.92

bleached nature, fibre qualities, weave, type and amount of sizing used and finally on the condition of climate and storage (Table 4).

The moisture contents below 7.5 per cent in the cotton fibres was found insufficient to cause appreciable loss in bundle strength (tenacity). Significant losses of 17.22 per cent in the tenacity of cotton was noticed at 19.7 per cent moisture in the fibres (Table 3).

The susceptibility of cotton to fungal decay was found directly correlated with the amount of alpha-cellulose present in the cotton but inversely proportional to the amount of hemicellulose and lignin contents in the fibres (Table 5).

As long as artificial surpluses and shortages of cotton continue to be created, the need for prolonged storage will continue. However the obvious action to protect cotton from damage is to reduce the period of storage.

Table 3. Changes in fibre properties of cotton during storage in cotton godowns in textile mills

Cotton varieties	Fibre moisture (%)	Change in colour in storage	Per cent loss in tenacity in storage
Khandwa X-1	0.4	No change	5.84
MCU-5	0.8	White to dirty	3.95
S-6	1.3	No change	4.69
F414 SG	1.5	No change	0.37
H_4 Khirkya	3.5	No change	3.23
H_4 Sendhwa	3.7	No change	3.15
H777 SG	4.2	White to dull white	3.87
V797	6.4	White to yellowish	4.57
A51-9	6.6	White to dirty	5.3
J-34 SG	6.6	White to dirty	5.29
J-34 RG	7.5	White to dull white	1.93
DCH 32	8.0	White to dirty	10.08
DCH 31	9.7	No change	8.08
S-4	9.3	White to dirty	9.95
H_4 Burwaha	9.3	No change	8.18
X-1	9.3	No change	9.01
MCU-11	9.3	No change	7.68
Kalagin	9.3	No change	9.83
H_4 Wardha	9.8	No change	11.22
Y-2	11.4	Yellowish to brown	12.74
G-11	11.4	No change	*
Ageti SG	11.5	No change	12.61
1007	11.7	No change	12.28
H_4 Dhamnood	12.3	No change	12.17
F414 RG	12.4	White to dirty	13.47
170 CO_2	12.5	No change	13.42
Wagad	12.5	White to dull white	13.97
Pakastani SG	13.2	White to dirty	17.85
H_4 Bhikagaon	13.2	No change	14.33
AKH_4-AKO	19.7	No change	17.22

Note :- The variations in fibre moisture and retained tenacity were found statistically highly significant.

*Not calculated.

5. CAUSAL FUNGI

Twenty-six fungal species were recorded from cotton and fabrics out of which two belong to Phycomycetes, one to Ascomycetes and twenty-three to Fungi Imperfectii group. Earlier the author reported three new fungal species incident on mill-made cotton fabrics[13]. In the present investigation, Aspergilli predominated. *Rhizopus nigricans, Mucor SP., Aspergillus fumigatus, A. flavus, A. niger, Cladosporium herbarum, Alternaria alternata* and *Fusarium SP.* were found occurring frequently on cotton whereas *Pullularia pullulans* showed restricted distribution.

Among these, *Alternaria alternata, Fusarium moniliforme* and *Cladosporium herbarum* were more common on cotton and fabrics during exposure, storage and in-service conditions.

Table 4. Susceptibility of cotton fabrics with per cent loss in their tensile strength (in parenthesis)* during conditions indicated

Susceptibility	Exposed	Stored	In-service
Wearables			
Highly susceptible	Print Poplene (81.62)	Hosiery (100)	Hosiery (83.37)
Highly resistant	Markeen (51.57)	Print Poplene (3.15)	Long cloth (23.80)
Intermediates	Hosiery Patra (52.50-70.71)	Markeen Print Poplene Print Poplene 5644 Print Pop 3114 Dyed Pop 3114 Print Dosooti Dyed Sheeting (7.42-96.55)	Markeen Patra Cambric Long cloth Dyed handloom Dyed rubia Voil (27.58-89.91)
Non-wearables			
Highly susceptible	Tapestry (74.19)	Back grey (91.70)	Curtain (71.91)
Highly resistant	Canvas L (31.15)	Canvas L (64.22)	Canvas H (31.66)
Intermediates	Canvas H Curtain (38.38-74.17)	Canvas H Tapestry Curtain (69.90-82.02)	Canvas L Tapestry Tentage Towel Bedsheet (42.30-61.15)

*Calculated on the basis of fresh fabrics

Table 5. Chemical analysis and moisture content of cotton fibres showing different degree of susceptibility to fungal attack during storage

Cotton variety	Loss in tenacity (%)	Moisture content (%)	α–cellulose (%)	Hemicellulose (%)	Lignin (%)
Highly susceptible					
AKH_4-AKO	17.22	13.2	68.9	11.2	9.4
Pakistani SG	17.85	11.5	73.4	12.0	12.7
Moderately susceptible					
S-4	9.95	6.6	48.4	25.6	21.9
Y-1	9.01	8.0	43.7	19.7	23.5
Poorly susceptible					
Khandwa X-1	5.84	0.8	24.9	37.4	33.5
F414-RG	0.37	0.4	29.5	41.8	29.7

Out of door exposure of cotton appear to allow the growth of many fungi not common in situations in which the destructive force of sunlight is free to act upon the organisms. Species of *Aspergillus, Penicillium, Alternaria, Fusarium, Myrothecium*

and *Trichothecium* occurred on exposed cotton fabrics especially at shady places or where light intensities were relatively low. *A. fumigatus* was exceedingly common on the samples of cotton and fabrics collected from varied situations differing in agro-climatic conditions.

Particularly during storage conditions Aspergilli predominated. *Humicola, Helminthosporium* and *Pullularia pullulans* occurred occasionly. During relatively damp storage situations mostly *Stachybotrys atra, Penicillium SP., Cladosporium herbarum* and *Aspergillus SP.* were common types. Fruiting bodies of *Phoma SP.* were profusely observed on canvas, hosiery goods during storage (Fig. 1-4).

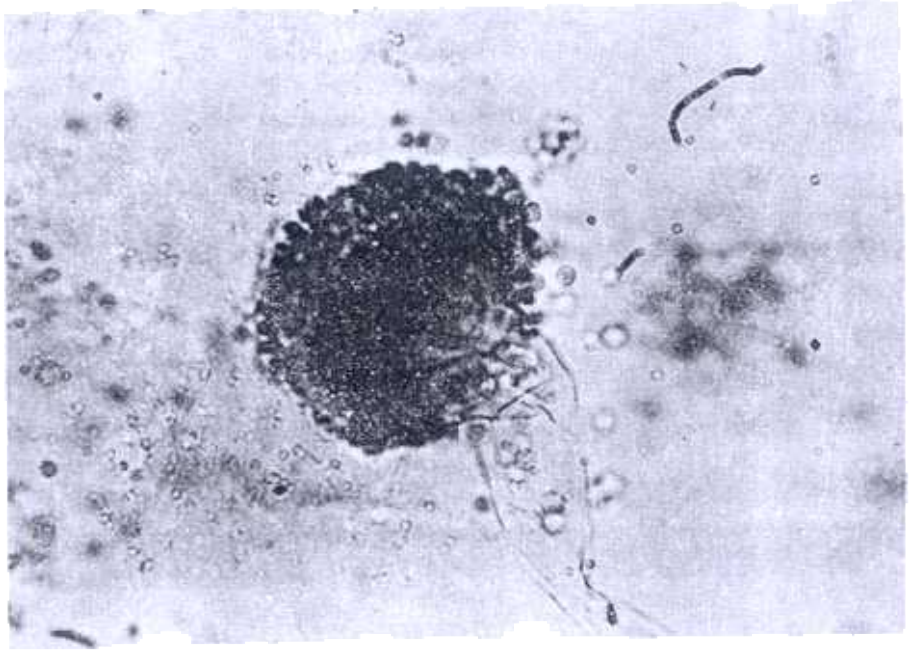

Figure 1. Conidial head of *Aspergillus fumigatus* (× 700).

Figure 2. Mycelium and conidial chain of *Cladosporium herbarum* (× 100).

Stachybotrys atra, Mucor SP., Rhizopus nigricans, Fusarium SP., Trichoderma viride and few Aspergilli were of widespread occurrence on cotton and fabrics during soil-contact storage conditions.

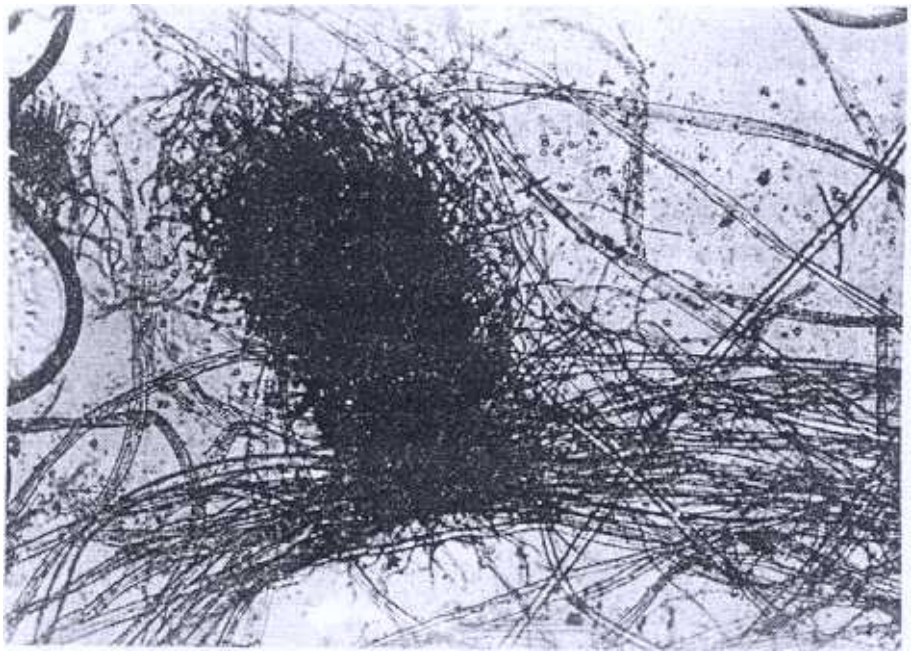

Figure 3. Perithecia of *Chaetomium globosum* on cotton (× 280).

Figure 4. Conidiophores of *Stachybotrys atra* on cotton (× 280).

The representative species of fungi isolated from cotton are listed below :

1.	*Aspergillus flavus*	14.	*Helminthosporium SP.*
2.	*A. niger*	15.	*Mucor SP.*
3.	*A. fumigatus**	16.	*Myrothecium verrucaria**
4.	*A. nidulans*	17.	*Phoma multirostrata*
5.	*A. sydowi*	18.	*Penicillium SP.**
6.	*A. terreus**	19.	*Paecilomyces varioti*
7.	*A. tamarii*	20.	*Pullularia pullulans*
8.	*Alternaria alternata**	21.	*Rhizopus nigricans*
9.	*A. tenuissima*	22.	*Sterile dematiaceae*
10.	*Chaetomium globosum**	23.	*Stachybotrys atra**
11.	*Cladosporium herbarum**	24.	*Trichothecium SP.*
12.	*Fusarium moniliforme**	25.	*T. roseum*
13.	*Humicola fuscoatra*	26.	*Trichoderma viride**

*Highly cellulolytic

It was evident that fungal imperfectii members constituted overwhelming majority and are therefore considered to play major role to commence decay of both cotton and cotton textiles. Since the fungi isolated from cotton are typical representatives of soil mycoflora, there is no doubt that contamination of cotton with soil particles constituted largely to the infection in the raw cotton.

6. EFFECT OF ENVIRONMENTAL CONDITIONS (HUMIDITY AND TEMPERATURE) ON THE DECAY OF COTTON AND FABRICS

The relative humidity of atmosphere directly influenced the tenacity of cotton. A marked increase in tenacity was observed over a range of relative humidity from 30 to 100 per cent. Such behaviour of cotton is obvious since cotton being hygroscopic material, absorbs moisture when it is transferred from dry to humid atmosphere[7]. Nearly 33 per cent loss in tenacity of cotton was observed after 120 days when r.h. approached 90 per cent. The loss showed a rapid increase in saturated r.h. above 90 per cent and went hand in hand with increase in fungal infection of fibres. When cotton is wetted, the strength showed a rapid loss within 90 days. Maximum decrease in tenacity was however observed in saturated humidity followed by in 95 per cent r.h. The observations were supported by statistical analysis (Table 6). The retained tensile strength and per cent loss in tensile strength of cotton fabrics under different r.h. showed almost similar pattern. Congo red value of cotton at different r.h. further confirmed the decay of cotton. Higher losses in tenacity of cotton were directly correlated with high Congo red values.

Different species of fungi tolerated different degrees of humidity during germination. While the spores of *Aspergillus niger, A. flavus, A. nidulans,* and *A. fumigatus* were capable of germinating in lowest r.h. of 30 per cent, those belonging to *Fusarium SP.* and *Cladosporium herbarum* required high humidity. Mildewing in cotton was apparent beyond 70 per cent r.h. only after a month associated with large fungal count, significant losses in tenacity and Congo red values. The fungal population was much greater in the range 90-100 per cent r.h. (Table 7).

Table 6. Mean values of retained strength and per cent loss in strength of cotton (measured in terms of tenacity, Stelometer 0″ gauge g/t) and cotton fabric (measured in tensile strength in kg) stored in different relative humidities at 30°C

Relative humidity (%)	Retained strength				Per cent loss in strength over control			
	30 days	60 days	90 days	120 days	30 days	60 days	90 days	120 days
Cotton								
30	26.33	33.40	26.60	24.66	–	–	–	–
50	29.40	31.70	28.00	22.40	–	–	–	6.66
70	29.10	34.20	29.33	23.33	–	–	–	2.79
90	30.40	35.33	31.20	16.00	–	–	–	33.33
95	32.70	27.40	23.66	9.06	–	–	1.41	62.25
100	31.00	27.00	21.40	2.44	–	–	10.83	89.83
100 (wet)	30.20	29.24	22.00	2.86	–	–	8.33	88.08
Control	24.00							
	33.66	24.66	22.33	22.33				
	28.33	25.33	23.00	22.00	–	–	–	–
	29.66	26.00	26.00	18.66	–	–	–	13.85
	34.33	27.00	20.33	11.66	–	–	6.14	46.16
	33.33	29.00	18.66	8.00	–	–	13.85	63.06
	23.66	27.33	16.33	3.33	–	–	24.60	84.62
	28.00	20.00	12.33	2.00	–	7.6	43.07	90.76
	21.66							

The original mycoflora on the cotton in present case consisted of many different species common to raw field cotton[14]. These fungi germinate and grow in competition with many others on cotton substrate. The fungi predominating at the end therefore, are in real sense potent cellulose destroyers causing mildew. Moisture is necessary for fungal growth but the latter are by no means destroyed by desiccation. The spores remain in dormant form for several years during storage. If all the cotton produced in a season is consumed, the problem of storage does not arise. There are however times, when atleast a small portion of a season's crop has to be carried over to next year by the trade. Under humid storage conditions, the dried spores of fungi present initially in the cotton revert to active growth and impart their destructive action. As a result, the cotton is sold at discounts.

Practically insignificant variation in bundle strength of cotton was observed at 5—40°C at all humidity levels till 60 days, though almost in all cases increase in bundle strength was well marked in comparison to control . This is most probably due to hygroscopic nature of cotton. After 90 days of incubation, cotton showed a gradual decrease in strength from 25°C onward reaching maximum in the range 30-35°C. These losses were however found more pronounced after 120 days (Table 8). The inverse relationship between retained tenacity of cotton and per cent loss in tenacity was statistically substantiated by negative value of correlation coefficient. Thus minimum retained tenacity had simultaneously shown maximum loss in tenacity.

The qualitative loss in strength of fabric was found much higher than that of cotton on each sampling. The reason for this may be attributed to the presence of sizing material on the fabric which support pronounced fungal growth[15]. The fungi concerned with the decay of cotton are mostly mesophytic types showing optimum range of 30-35°C. The effect of humidity is, in fact a function of temperature. The range of humidity over which germination of fungi occurs, is greatest at optimum temperature. The data have also shown that effect of temperature is not as critical as that of humidity.

Attack of cotton by fungi is always a result of improper or incomplete storage under optimum conditions of temperature and humidity. The cotton can be protected by clearly following standard warehouse construction methods and general practices peculiar to country and climate concerned. The physical methods to be conveniently used for long scale and long term storage of cotton is either low temperature storage or the application of heat to raise air and godown surface temperature to a level which may cause death of all stages of life history of fungi.

Table 7. Fungal count of cotton and fabric after incubation at 30°C and relative humidities indicated

Relative humidity (%)	Fungal count × 10^3 per gram cotton			
	30 days	60 days	90 days	120 days
Cotton fibres				
30	2	2	2	3
50	3	3	3	5
70	7	8	10	18
90	9	10	15	26
95	18	30	35	45
100	19	35	36	50
100 (wet)	18	36	35	52
CD at 5% P	8.38			
Cotton fabric				
30	2	2	2	2
50	2	3	3	3
70	4	4	8	14
90	6	7	15	23
95	15	19	24	30
100	17	33	36	47
100 (wet)	18	35	36	48
CD at 5% P	8.37			

Original count per gm Cotton fibres – 3×10^3, Cotton fabric – 2×10^3

Original mycoflora of cotton and fabric : *Aspergillus*, *Penicillium*, *Mucor*, *Rhizopus*, *Alternaria*, bright coloured Deuteromycetes

Table 8. Mean value of retained bundle strength (tenacity) measured by Stelometer 0" gauge in gram per tex and per cent loss in tenacity of cotton stored at different temp. and relative humidities as indicated

Temp. (°C)	Relative humidity (%)	Retained tenacity (g/t)				Per cent loss in tenacity			
		30 days	60 days	90 days	120 days	30 days	60 days	90 days	120 days
	80	33.33	34.80	34.33	34.86	4.33	0.11	1.46	
5	90	34.00	33.00	34.86	34.70	2.4	5.78		
	95	33.43	32.66	34.70	34.54	4.04	6.25		
	80	36.92	37.46	36.00	29.70	–	–	–	14.75
25	90	35.66	37.60	34.54	28.80	–	–	0.86	17.33
	95	34.16	36.50	33.46	28.15	1.95	–	3.96	19.44
	80	37.40	39.40	33.00	23.17	–	–	5.28	33.49
30	90	36.36	39.13	32.00	23.23	–	–	8.15	33.32
	95	36.00	36.84	31.00	21.97	–	–	11.02	36.94
	80	38.10	40.65	38.57	19.60	–	–	–	43.74
35	90	38.00	39.20	35.30	20.40	–	–	–	41.44
	95	35.00	38.00	34.00	19.63	–		0.56	43.65
	80	38.10	40.65	36.40	30.13	–	–	–	13.51
40	90	38.00	39.20	32.30	28.74	–	–	7.29	17.50
	95	35.00	38.00	30.00	27.42	–	–	11.02	21.29
	Control	34.84							
	CD at 5% P	1.23	3.34	2.03	2.00				

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