UTILIZATION OF LIGHT MICROSCOPY IN PREDICTING COTTON STRENGTH AND FIBRE DAMAGE

BY

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ABSTRACT:

Tensile strength and damage of cotton fibres could be assessed by making use of light microscopy. In essence, a solution was prepared consisting of $ZnCl_2$ (100g.), KI (32 g.), water (34 ml) and I_2 (till saturation). This solution was used as a swelling agent for cotton during microscopic examination. Differences in numbers, shape, size, and sequences of beads of the secondary wall as well as the shape of the primary wall have been taken to predict, (a) magnitude of damage, (b) location of damage, (c) kind of damage, whether chemical or mechanical (d) maturity of fibre, and (e) tensile strength.

INTRODUCTION:

Cotton fibre is the purest form of natural cellulose and has very little lignin or pictin compouned with the cellulose as flax, jute, hemp or wood. However, it still contains several unwanted impurties (1). Nearly 6% of the fibre weight is impurities that need to be removed to prepare cotton for most textile uses.

The need for removal of impurities is obvious to make grey fabrics white and absorbent and to prepare them for dyeing, printing or chemical finishing. The effect of their various treatments is to bring about deterioration and degradation of the cotton fibres in the fibric.

Deterioration of the fibre is usually assessed by strength measurement,whereas fibre degradation is aaseseed by determination of degree of polymerization, or fluidity, copper number and carboxyl groups (2). Disadvantages of these methods are:-

1) They are tedious and lengthy.
2) All the methods should be carried out to assese deterioration and degradation.

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3) None of these methods can give reliable informations about the location of damage in the fibre.
4) None of these methods can detect the kind of degradation whether chemical or mechanical.

Thus, it is obvious that a rapid and simple method for assessing degradation and deterioration of fibres is badly needed. The present work was undertaken to fulfil this gap.

In essence, the method described here is based on immersing the cotton fibre in a particular swelling agent then examining the swollen fibre using a light microscope. Differences in numbers, shape, size, and sequences of beads of the secondary wall as well as the shape of the primary wall have been taken to predict, (a) magnitude of damage, (b) location of damage, (c) kind of damage, whether chemical or mechanical, (d) maturity of fibre, and (c) tensile strength.

EXPERIMENTAL:

Materials:

Varieties of Egyptian cotton fibre which are commercially available together with four variaties which are still under test have been used. The commercial cotton fibres are Giza 66, Giza 68, Giza 70 and Giza 75. The new varieties which are still under test include Giza 76, Giza 77, Giza 79 and Giza 82. In addition to the Egyptian cotton varieties indicated above, Indian cotton and American cotton have been used in this investigation.

Thermal Treatment:

Unless otherwise stated, the cotton fibres are subjected to heat treatments in a laboratory oven at 140 °C for varying periods of time. The latter ranges from 15 minutes to 75 minutes.

Hypochlorite Treatment:

Treatment of the cotton fibres with sodium hypochlorite was carried at room temperature (27 °C) and pH 7 for 2 hours using different concentration of sodium hypochlorite. Three concentrations of the latter were used viz 1 g/l, 3 g/l, and 6 g/l available chlorine. At the end of the reaction, the cotton fibres were thoroughly washed and finally dried at ambient conditions.

Treatment With Sodium Hydroxide:

Cotton fibres were treated at the boil with an aqueous solution of sodium hydroxide at a concentration of 1%, 2%, 3% or 4% for 45 minutes. The fibres were then thoroughly washed, neutralized with dilute acetic acid, thoroughly washed, and finally dried at ambient condition.

Preparation of Swelling Agent:

The swelling agent used was prepared as follows:-

100 g. Zinc chloride and 32 g. potassium iodide was dissolved in 34 ml. water then iodine was added till saturation.

Microscopic Examination:

A light microscope with an attached camera and a heating disc was used. Adjustment of the temperature could be achieved through connection of the disc with Universal Inclubator Type U_3 (KOVO).

All the measurments were conducted at a constant slide temperature of 62 °C.

Tensile Strength:

The tensile strength was measured using Pressley Strength Tester at zero gauge i.e. 0.465 in. gripped in the clamps.

RESULTS AND DISCUSSION:

To start with, different varieties of cotton fibres were treated with the swelling agent and examined using the light microscope. Figures 1, 2, 3 and 4 show longitudinal views of Giza 66, Giza 68, Giza 70 and Giza 75 respectively. Figures 5, 6, 7 and 8 show similar views for Giza 76, 77, 79 and 82 respectively. It is clear that for a given cotton variety the fibresshow spherical swelling, spiral swelling or a combination of both.

That is, the method in question cannot provide a precise distinction of the variety of cotton. However, it was observed that the new Egyptian cotton varieties exhibit more spiral swelling than spherical swelling(Fig. 5). The old varieties (Figs. 1-4), on the other hand, show mainly spherical swelling.

Magnitude of Damage:

Trials have been made to find out the magnitude of damage in a cotton fibre using the light microscope. For this purpose different cottons were subjected to mechanical stress by using Pressley Strength tester till the point of breakage. The original fibres as well as the broken fibres were examined with the light microscope after the fibres being treated with the swelling agent. The number of beads in a fibre length of 0.465 in. for every longitudinal view of the fibres was counted. Percentage of damage may be calculated according to the following formula:

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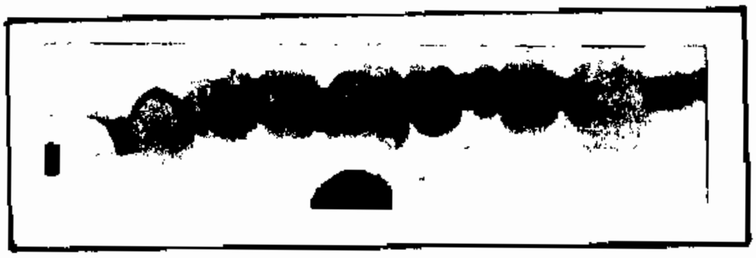

Fig.1

Fig.2.

Fig.3.

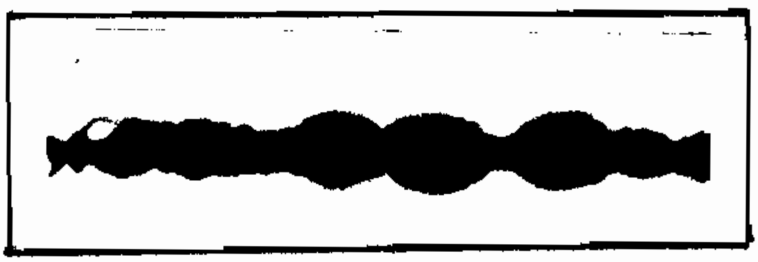

Fig.4.

Fig. 1,2,3 and Fig.4, shows the longitudinal views of Giza 66,60, 70 and 75.

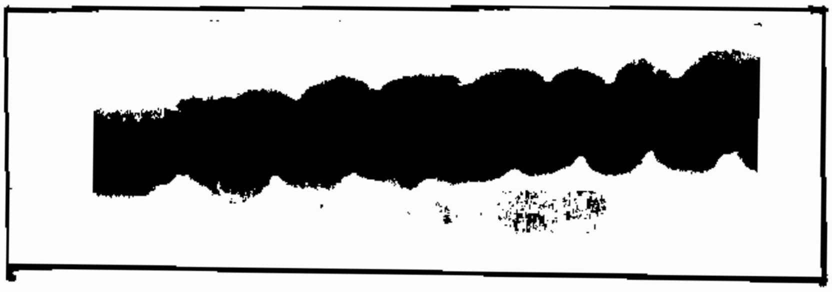

Fig.5.

Fig.6.

Fig.7.

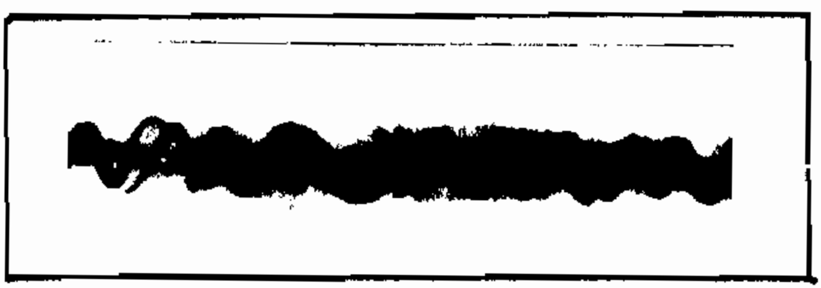

Fig.8.

Fig. 5,6,7 and Fig.8, shows the longitudinal views of Giza 76,77,79, and 82.

Table (I): Effect of Mechanical Stress on Damage of Different Varieties of Cotton Fibres. (Zero Gauge Pressley Tester)

Varieties of Cotton	Pressley Index lbs/mg.	N_o	N	% Damage Due To Tension
Giza 70	11.40	110	100	9.09
" 82	11.10	106	94	11.32
" 68	10.40	98	86	12.24
" 75	10.33	92	84	8.60
" 76	10.30	88	80	9.00
" 77	10.20	82	73	10.90
" 79	9.90	76	67	11.80
" 66	8.80	68	56	17.60
American	7.80	52	40	23.07
Indian	5.30	49	22	55.10

Table (II): Effect of Mechanical Stresses on Damage of Giza 79 and Giza 82.

Variety of Cotton	Type of Stress	Average number of beads before treatment (Raw) N_o	Average number of beads after treatment N	Damage %
Giza 79	Compression	47.2*	30.9*	34.5
" 82	Tension	140+	84.5+	39.6
" 82	Bending + Compression	140+	40+	71.42

* Fibre length is equall to 0.232 in.

\+ Fibre length is equall to 0.589 in.

Tension (1/8" gauge), Compression (800 g/cm).

$$\% \text{ Damage} = \frac{N_o - N}{N_o} \times 100$$

Where N_o is the number of beads before treatment and N is the number of beads after treatment.

Table (I) shows the percentage of damage brought about under the influence of mechanical stress (Using Pressley tensile tester) for different varieties of cotton. It is clear that the mechanical stresses induced during measuring the tensile strength of cotton fibres is accompanied by a substantial damage in the cotton fibres. This is observed regardless of the variety of cotton used. However, the magnitude of damage depends on the cotton variety. Of the varieties examined Giza 75 shows the lowest damage whereas Indian Cotton shows the highest damage. American cotton stands in a midway position between the Egyptian cotton and the Indian cotton. It is as well to emphasize that with the exception of Giza 66, the magnitude of damage obtained with all cotton varieties is not that striking, reflecting the superiority of Egyptian cottons.

Damage caused under the influence of different types of mechanical stresses viz tension, compression and combined bending and compression was effected by:

a) using Pressley Strength tester but at 1/8 in. gauge (stresses as a result of tension).
b) Placing the fibres under a load of 800 g. per Cm. (stresses as a result of compression).
c) bending the fibres in the form of a loop at a load of 800 g/Cm.
(stresses as a result of bending and compression)

The damage was then assessed by the light microscope using the swelling agent in question. The results obtained are summarized in Table (II).

As can be seen from Table (II), the magnitude of damage depends on the type of stress. Combined bending and compression cause the highest damage. An interesting feature is that the damage brought about under the same type of tension differs (compare Tables I and II) with the gauge length. The longer the gauge length the higher the damage, a phenomenon which is usually encountered on tensile strength measurements due to increasing number of weak points.

Table (III) shows the percentage of damage conferred on Giza 75 and Giza 77 as a result of sodium hypochlorite treatment. It is evident that the treatment of cotton fibres with sodium hypochlorite results in a considerable damage of cotton fibres. The magnitude of the damage relies on the concentration of the hypochlorite solution and the variety of cotton.

Table (111): Effect of sodium Hypochlorite Concentration of fibre damage.

Cotton	NaOCL Concentration g/1	N_o	N	% Damage
Giza 75	none	92	92	00.0
	1	92	79	14.1
	3	92	25	72.8
	6	92	2.4	97.4
Giza 77	none	82	82	00.0
	1	82	79	3.6
	3	82	14	82.9
	6	82	0	100

Table (IV): Effect of Na OH Concentration on Fibre Damage.

Cotton	Na OH. Concentration %	N_o	N	%Damage
Giza 75	none	92	92	00.0
	1	92	90	2.1%
	2	92	84	11.8%
	3	92	75	18.4%
	4	92	64	30.4%

Giza 75 acquires more resistance to hypochlorite attack than Giza 77, though both cotton varieties are seriously affocted at higher sodium hypochlorite concentration. The hypochlorite seems to oxidize the fibres and, in particular, the primary wall. The latter is perhaps converted to short chains degraded products which are removed during washing.

It should be emphasized that 100% damage does not mean that fibres are completely degraded. Indeed it means that the primary wall does not exist any more. That is, full degradation of the primary wall occure at higher concentratione of the hypochlorite solution. This will be detailed later (See below).

Table (IV) shows the percentage of damage undergone by Giza 75 due to treatment with sodium hydroxide for 45 minutes at the boil. The data indicate that very little damage occure when the fibres were boiled in 1% alkli for 45 minutes. Increasing the alkali concentration 2% causes a substantial damage. Further increase in the magnitude of damage could be recorded upon boiling the fibres for the same period in 3% sodium hydroxide solution. A damage of Ca 30% is obtained at an alkali concentration of 4%. In other words, the magnitude of fibre damage increases by increasing the alkali concentration. This suggeste that the oxidation action of sodium hydroxide would be more at higher concentration thereby causing partial disintegration of the primary wall.

Table (V) showe the percentage of damage undergons by Giza 68 and Giza 76 due to heat treatment. It is clear that thermal treatment at 140 °C causes a considerable damage in cotton fibre. The magnitude of damage depends on duration of treatment as well as the variety of cotton. As the duration of treatment increase the magnitude of damage increases. Also the variety of cotton does effect the magnitude of damage since, as the data of table (V) imply, the Giza 76 is more resistant to thermal treatment than Giza 68.

Location of Damage:

The light microscope examination is useful in detecting the location of mechanical damage. At the portion of the fibre that sufforod from the mechanical stress, high swelling occurs while the unimpaired portion would show much less swellability. Also the number of beads would not decrease much. This may be realized from Fig. (9). In case of chemical damage, on the other hand, it is very difficult to locate damage since the damage usually oocurs throughout the entire fibre.

Table (V): Effect of heat treatment at 140 °C on fibre damage.

Variety of cotton	Time of heating (min)	N_o	N	Damage %
Giza 68	none	98	98.00	00.0
	15	98	67.75	30.8
	45	98	41.50	57.6
	75	98	29.00	70.4
Giza 76	none	88	88.00	00.0
	15	88	79.52	9.6
	45	88	50.00	43.1
	75	88	43.20	50.9

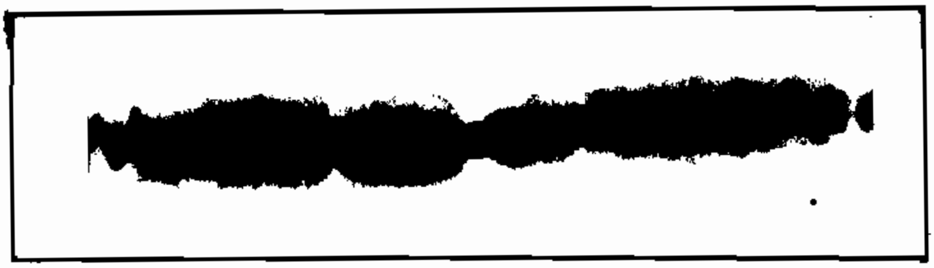

Fig.9.

Fig.9 shows the effect of scouring with N_aOH at concentration of 4% for 45 minutes.

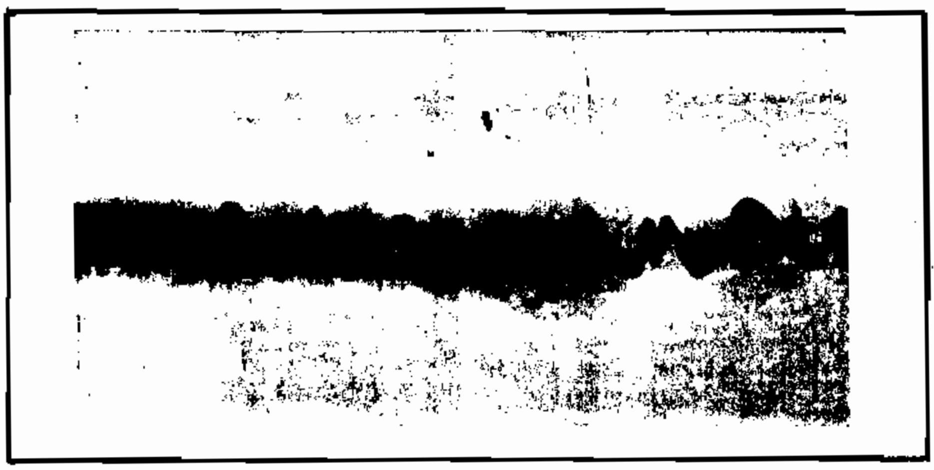

Fig.10.

Fig.10. shows the effect of mechanical degradation.

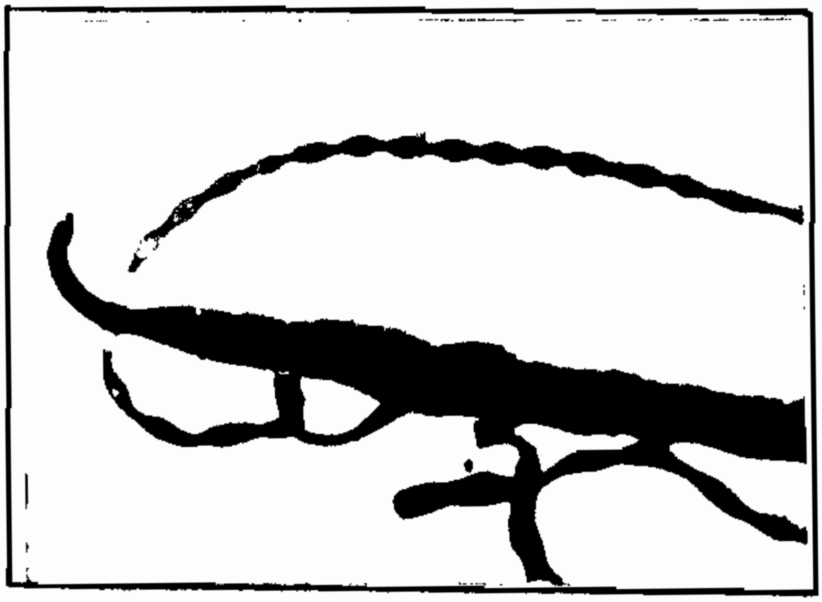

Fig.11.

Fig.11. shows the longitudinal viwe of mature and immature fibre.

Kind of Damage:

It is quite easy to distinguish between the chemical and mechanical damage by making use of swollen longitudinal views of cotton fibres using the light microscope. As shown in Fig.(10) the number of beads in mechanically degraded fibres is greater than those chemically degraded. Also location of the damage is clear in the mechanically degraded fibres. This is not the case with the chemically degraded fibres since it is very difficult to detect location of damage in this case.

Fibre Maturity:

As to be expected the immature fibres would not exhibity noticeable swelling in the swelling agent. Mature fibres, on the other hand, would show considerable swelling. Figure 11 indeed, is tallied with this expectation where the swollen fibres appear almost cylindrical while the immature fibre a corkscrow shape.

Relation Between Number of Beads and Tensile Strength:

In an attempt to find out wheather there is a relation between the number of beads and tensile strength, two parallel analysis have been made. In first the Pressley Strength at zero gauge as woll as the number of beads derived there of was lend to calculation of the coefficient of correlation. In the second, the same correlation was made but the number of beads of the original fibres at the same length was used in the calculation. The results obtained aro shown in Tables (VI and VII), respectively.

It is clear from Table (VI) that the correlation between average number of beads for a fibre length of 0.465 in. and Pressley Index is positive. Furthermore, the value of the correlation coefficient amounts to Ca 0.93. This indicates that there is excellent correlation between tensile strength and number of beads.

Table (VII) shows the correlation between Pressely Index and average number of beads for the same fibres used for measuring the Pressley Index. Here too, it is clear that the correlation is positive and excellent since the value of the correlation coefficient amounts to 0.97. It is well known that if the value of correlation coefficient is more than 0.80 the correlation could be described as excellent (5).

Based on the foregoing, it can be concluded that when a fibre acquires high number of beads, one would expect a high strength. On the contrary fibre of less number of beads would have a low strength. The results shown in Figures 12 is in full agreement with this expectation, where in the average

Table (VI): The correlation between average number of beads and fibre strength.

Variety of Cotton	X_i	Y_i	X' $(x_i-\bar{x})$	Y' $(Y_i-\bar{Y})$	$X'Y'$	X'^2	Y'^2
Giza 70	110	11.4	27.9	1.84	51.330	778.41	3.3856
" 82	106	11.1	23.9	1.54	36.806	571.21	2.3716
" 68	98	10.4	15.9	0.84	13.356	252.81	0.7056
" 75	92	10.3	9.9	0.77	7.623	98.01	0.5929
" 76	88	10.3	5.9	0.74	4.366	34.81	0.5476
" 77	82	10.2	-0.1	0.64	0.064	0.01	0.4096
" 79	76	9.9	-6.1	0.34	2.074	37.21	0.1156
" 66	68	8.8	-14.1	-0.76	10.716	198.81	0.5776
American	52	7.8	-30.1	-1.76	52.976	906.01	3.0976
Indian	49	5.4	-33.1	-4.16	4.160	1095.61	17.3056
	$\bar{X}$ = 82.1	$\bar{Y}$ = 9.56	0	0	317.013	3972.9	29.1093

$$= \frac{x'y' - \frac{x'\ y'}{n}}{\sqrt{(x'^2 \frac{(x')^2}{n})(y'^2 \frac{(y')^2}{n})}} \quad \frac{317013}{\sqrt{3972.9 \times 29.1093}} \quad \frac{317.013}{\sqrt{340.07}}$$

$= 0.932199$

Where r is the correlation coefficient.

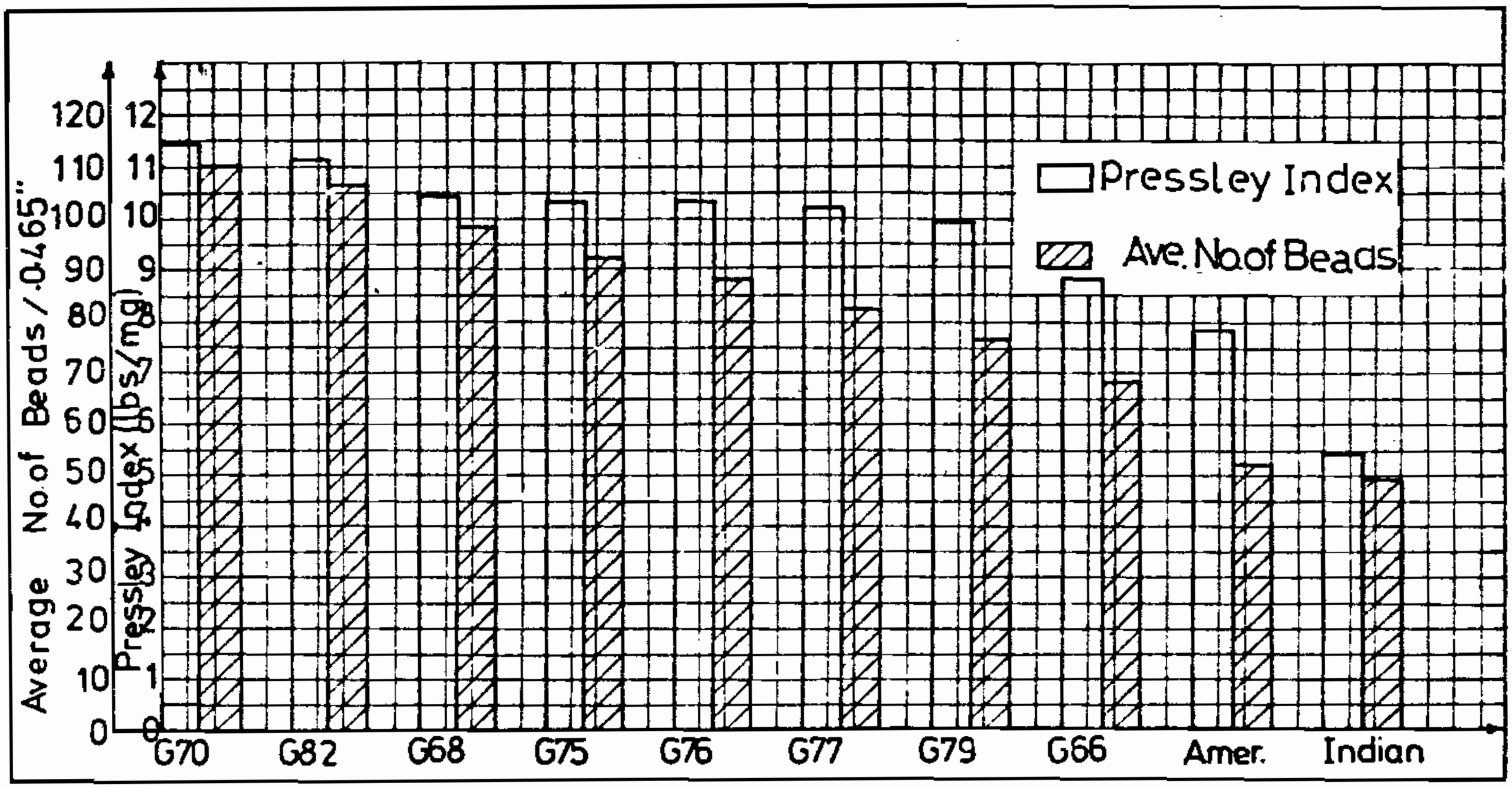

Fig. (12): Relationship of pressley index to average number of beads for different varieties of raw cotton.

Table (VII): The Correlation between Average number of Beads per 0.465" and Pressley Index.

Variety of Cotton	X_i N	Y_i obs/mg	X' $(X_i - X')$	Y' $(Y_i - Y')$	X'Y'	X'^2	Y'^2
Giza 70	100	11.40	29.8	1.84	54.832	888.04	3.3856
" 82	94	11.10	23.8	1.54	36.652	566.44	2.3716
" 68	86	10.40	15.8	0.84	13.272	249.64	0.7056
" 75	84	10.33	13.8	0.77	10.626	190.44	0.5929
" 76	80	10.30	9.8	0.74	7.252	66.04	0.5476
" 77	73	10.20	2.8	0.64	1.792	7.84	0.4096
" 79	67	9.90	-3.2	0.34	1.088	10.24	0.1156
" 66	56	8.80	-14.2	-0.76	10.792	201.64	0.5776
American	40	7.80	-30.2	-1.76	53.152	912.04	3.0976
Indian	22	5.40	-48.2	-4.16	200.512	2323.24	17.3056
n-10	x'		0	0	389.97	5445.6	29.1093

$$= \frac{x'y' - \frac{x'\ y'}{n}}{\sqrt{\left(x'^2 \frac{(x')^2}{n}\right)\left(y'^2 \frac{(y')^2}{n}\right)}} = \frac{389.97}{\sqrt{5445.6 \times 24.1093}} = \frac{389.97}{\sqrt{158517.6}}$$

$$= 0.97947958$$

Where r is the correlation coefficient.

number of beads obtained with differnt varieties of cotton is plotted against their Pressley Index.

A further support for this relation can be realized from Figs.(13, 14 and 15). These figures show the average number of beads of two varieties of cotton viz Giza 75 and Giza 77 and corrsponding Pressley Index before and after the fibres have been subjected to sodium hypchlorite treatments. As can be seen the Figures reveal one common feature. i.e. the higher the number of beads the higher the tensile strength. Figure (16) shows three-dimensional diagram for Giza 75 including the following:

1) relation between average number of beads and concentration of sodium hypochlorite;
2) relation between Pressley Index and sodium hypochlorite concentration;
3) relation between average number of beads and Pressley Index.

Figure (17) shows similar three-dimensional diagram but for Giza 77.

It may be argued that why the fibre retains considerable strength while the damage reaches 100%. The answer lies in the fact that 100% damage means that the Primary wall is completely degraded. Contribution of the primary wall in the tensile strength in this case is perhaps nil. Hence the secondary wall which is also affected by the treatment is responsible for the measured tensile strength.

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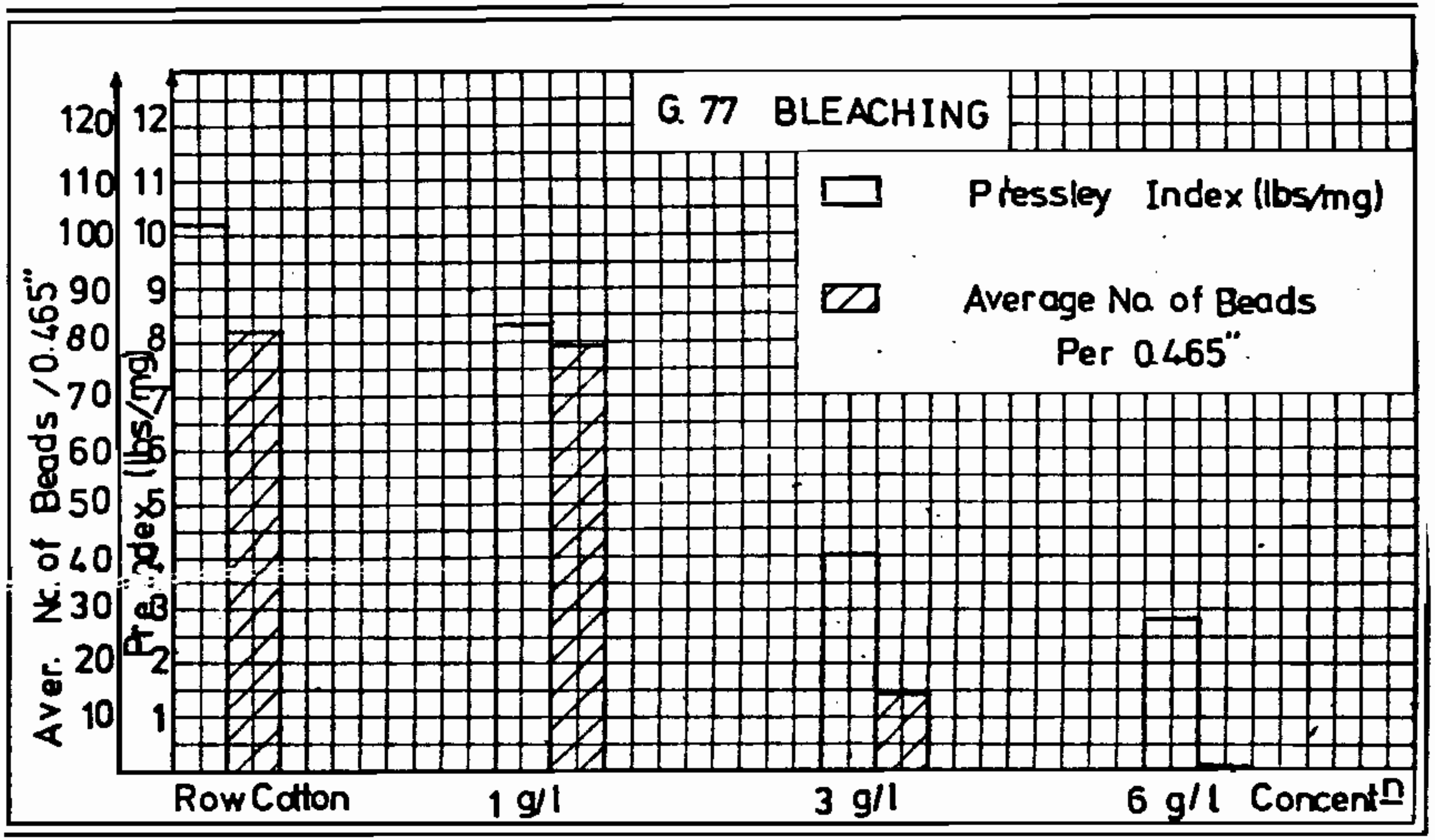

Fig.(13): Comparison of pressley index and average number of beads with varying N_aOCl concentration.

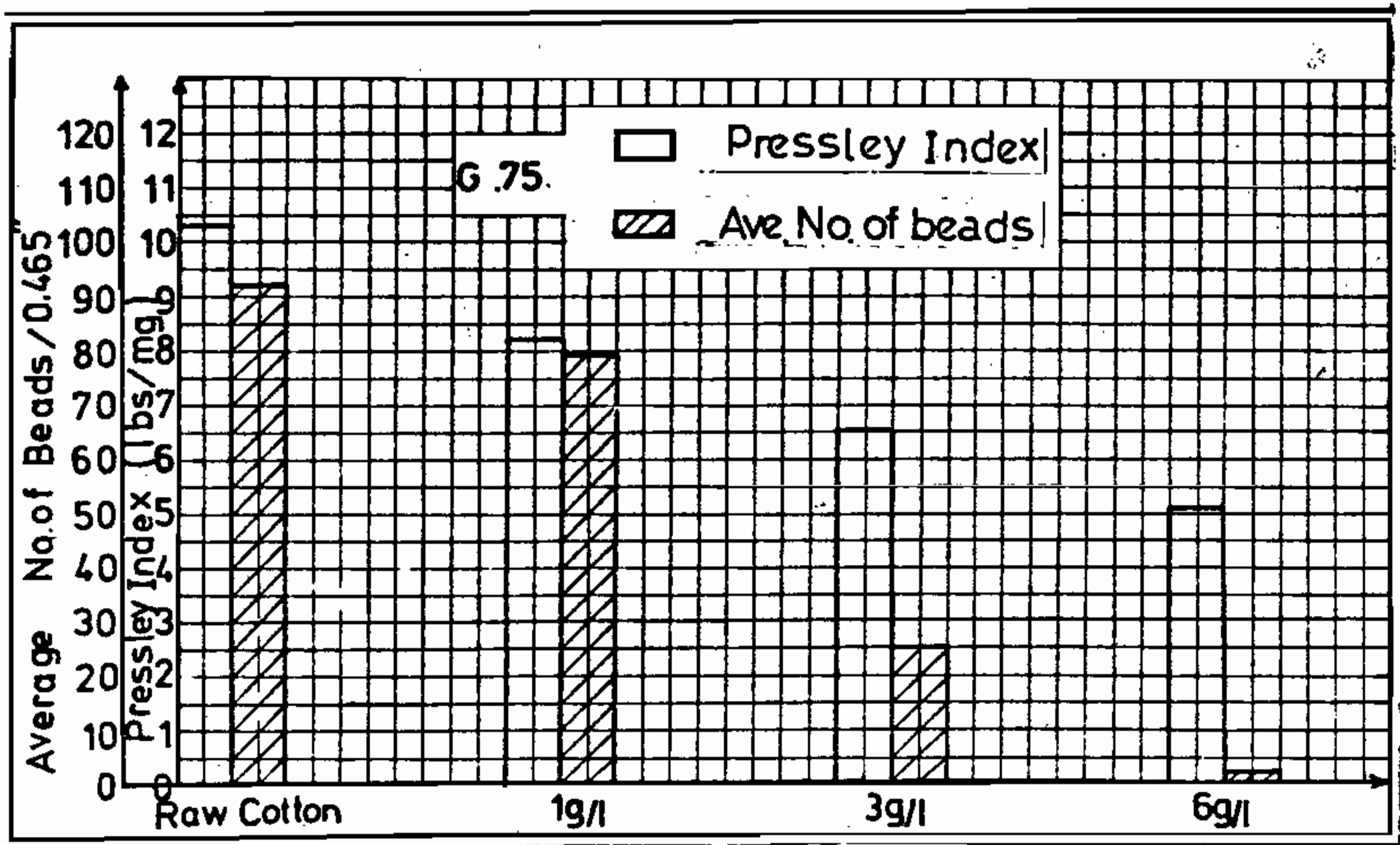

Fig.(14): Comparison of pressley index and average number of beads with varying N_a OCl concentration.

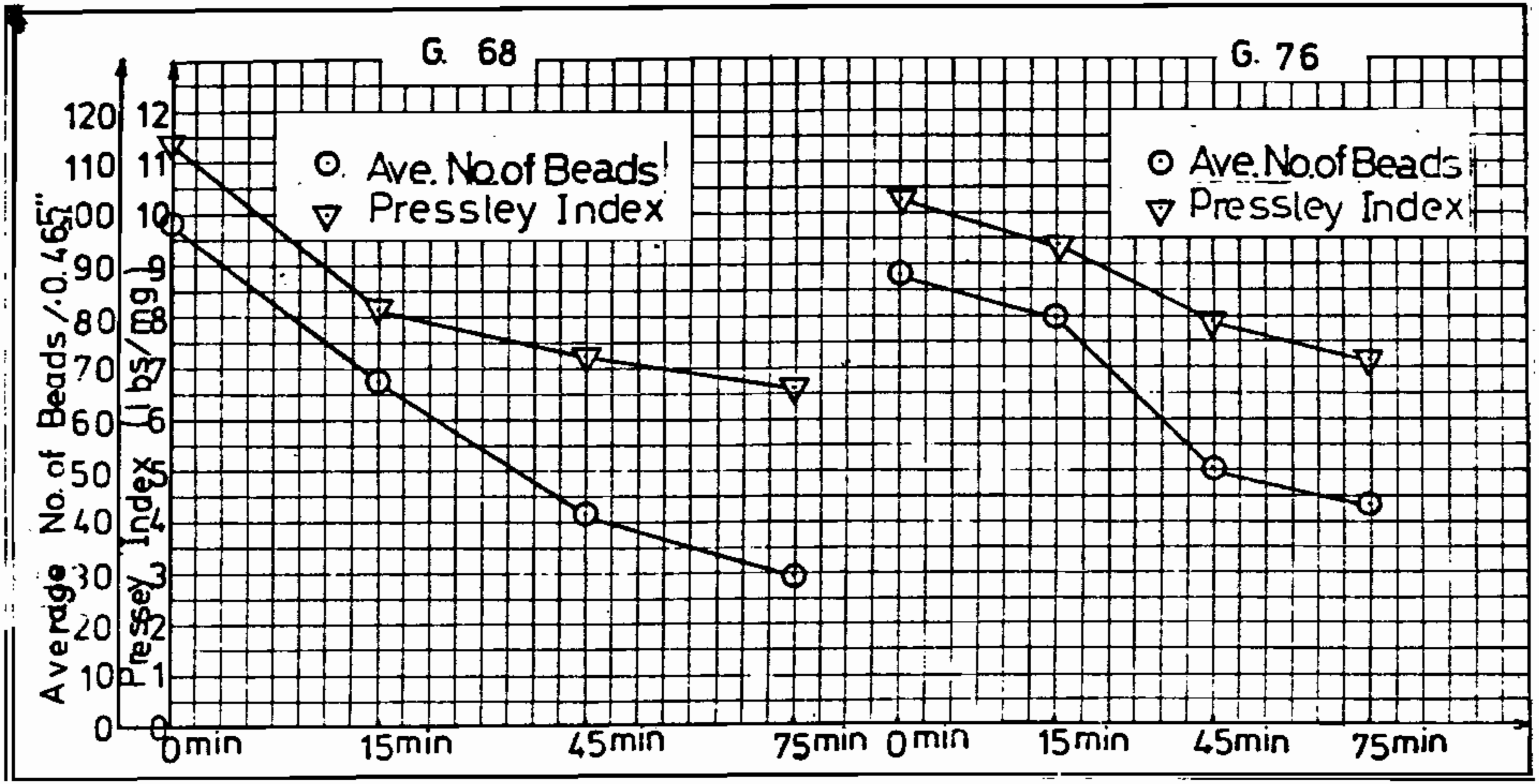

Fig.(15): Effect of heat treatment in a laboratory oven at 140°C for varying periods of time on Pressley Index and average number of beads of Giza 68 and Giza 76.

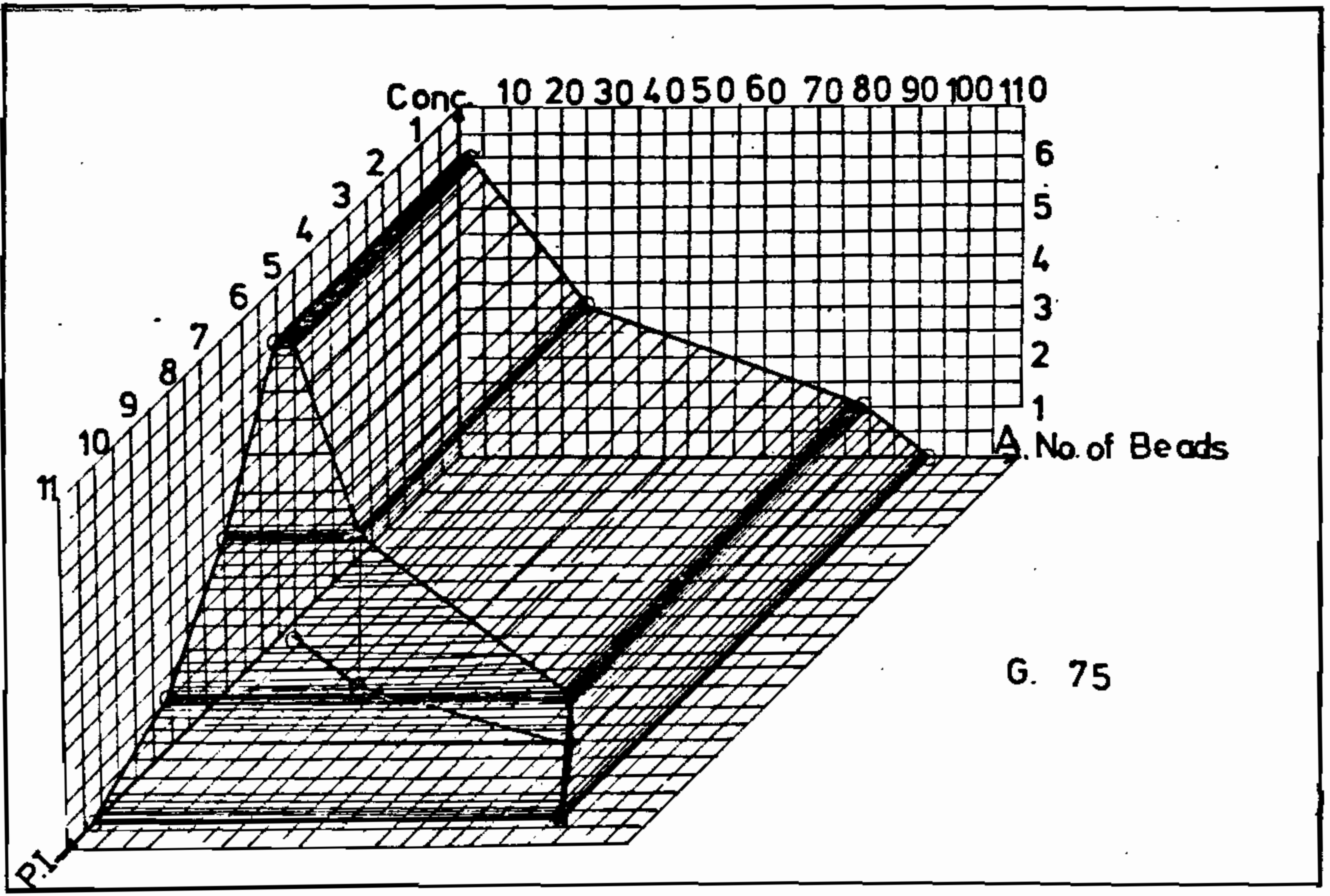

Fig.(16): Three dimensional diagram for raw and bleached cotton.

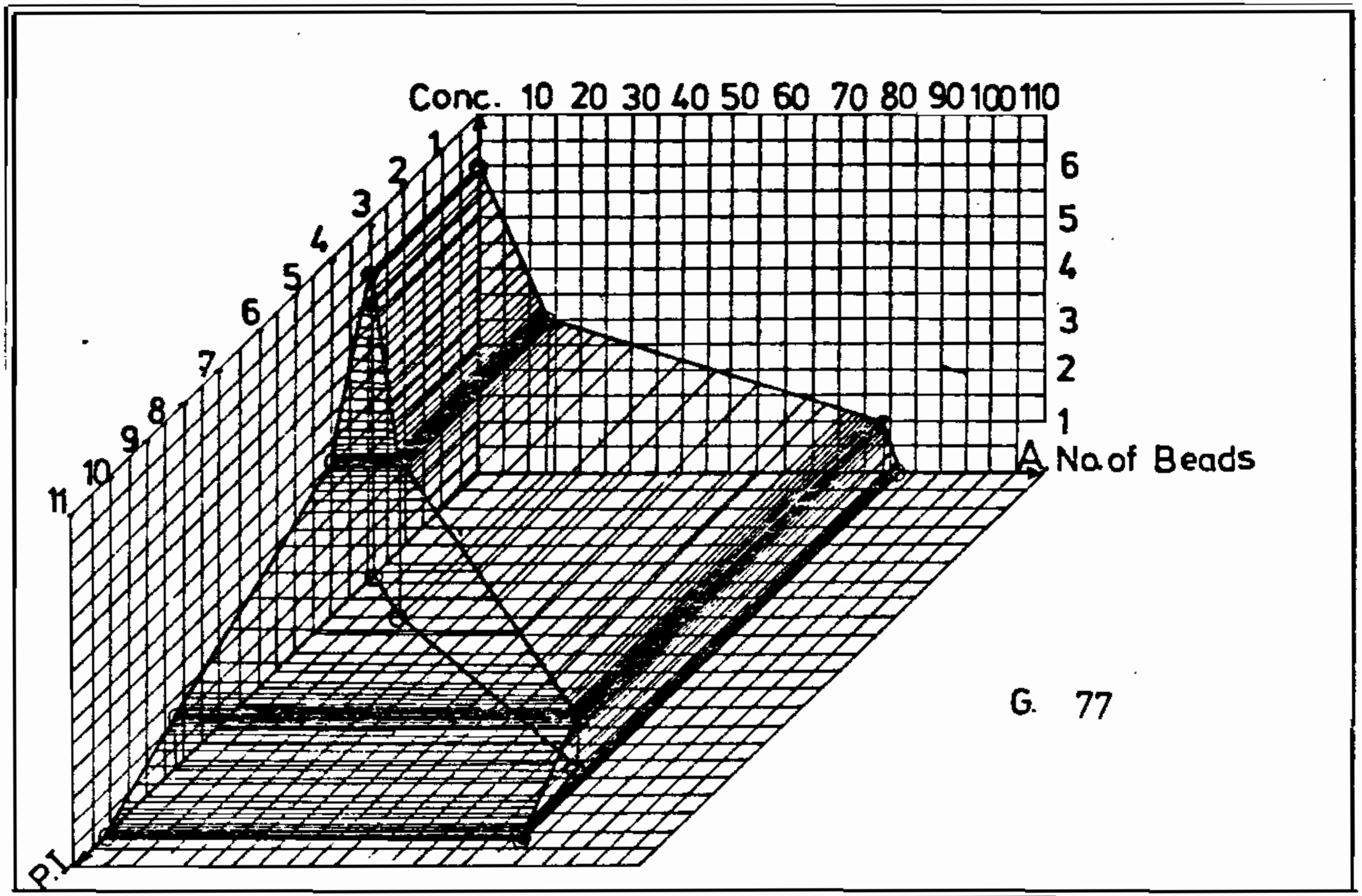

Fig.(17): Three-dimensional diagram for raw and bleached cotton.