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# Quality of Summer Knitted Fabrics Produced From Microfiber/Cotton Yarns

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## ABSTRACT

The most considered comfortable summer wear is that produced from natural fibers specially cotton. But cotton fibers have low Ultra Violet (UV) blocking properties for sun protection. However polyester fibers have usually good (UV) protection, so it is common to blend cotton(C) with polyester especially microfibers (M) to have a perfect summer fashion with good UV protection. Fabric construction also affects the comfort ability. This research studies the quality of fabrics of different blends that were carried on knitting machine from cotton and microfiber polyester yarns. Four production parameters were applied. By analyzing the tested results, an index for clothing performance quality was proposed and the operating conditions for the best index could be detected.
**KEY WORDS**: Summer Clothing, Performance, Quality, Blending, Optimum Condition.

## 1. INTRODUCTION

In the textile domain, the research and innovative activity primarily aims to find textile fibers with new properties. It can respond possible to dynamic consumers' requests, and also to use ecologic and natural materials. Therefore, there is on-going research regarding those materials which can correspond to a specific category, mixing the natural materials with the synthetic ones and applying new technologies [11]. Polyester or polyester blends may be the most suitable fabric type for UV protective garments [7]. As a result Polyester fibers are widely used in active wear and sportswear. However, their hydrophobic property limits their broad application. Therefore, it is necessary to design a kind of polyester fiber with both a good hygroscopic character and quick dry property. Micro-denier polyester is ideal for wicking perspiration away from the skin [3]. Microfibers properties are influenced in many interesting ways, as denier per filament are reduced [6]. Microfiber fabrics are generally lightweight, resist wrinkling, have a luxurious drape, retain body shape, and resist pilling. They are also relatively strong and durable in relation to other fabrics of similar weight, more breathable and more comfortable to wear [13].

Consumers generally consider lightweight non-synthetic fabrics to be the most comfortable for summer wear[7]. No other fiber can give a better performance than cotton as far as the comfort requirements of fabrics are concerned although better durability and aesthetic look might be achievable in the synthetics [12]. Beside that cotton and other natural fibers have lower degree UVR absorption than synthetic fibers such as PET [14], Cotton also swells in each wet treatment which leads to shrinkage of knitted fabric. Shrinkage of knitted fabric increases its tightness, and weakened the transmission of UV radiation through tighter fabrics that improve protection against UV rays [5]. Therefore, cotton blend fabrics have been increasing in popularity in recent years because they combine the best properties of each of the components [1].

Fabric construction parameters, the manner of patterning and technological processes of manufacture, associated with the structure and properties of used fibers and the yarns. Fabric construction is dependent on fabric mass and thickness, yarn insertion, fabric surface cover and its fullness [2]. The rate of airflow through a fabric under differential pressure applications between its two surfaces is believed to be important in determining many of the physical and mechanical properties of it [16]. Air permeability is a hygienic property of textiles which influences the flow of gas from the human body to the environment and the flow of fresh air to the body. Air permeability depends on fabric porosity, and its cross-section and shape [4]. Knitted fabrics are known for their excellent comfort properties. Due to the manner in which yarns and fabrics are constructed, a large proportion of the total volume occupied by a fabric is, usually, airspace [9]. Fabric thickness and the applied pressure drop are the other dominant factors that affect permeability. However it is a complex physical phenomenon due to the fibrous character and highly non-uniform structure [16].

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Ultraviolet protection factor, UPF values, indicates the ability of fabrics to protect the skin against sun burning. Therefore, it is important to protect the people from the ultraviolet radiation falling on garments and sun-screening textiles such as tends [5]. Besides, the construction parameters and wear conditions of the textile materials, moisture and additives incorporated in processing also affect the UPF of the textile materials [14]. Thicker, denser fabrics transmit less UV radiation. Thickness is most useful in explaining differences in UV transmission when differences in percentage cover factor are also accounted for. Various textile qualities affect the UV protection factor of a finished garment; important elements are the fabric porosity, type, color, weight, and thickness. The application of UV absorbers in the yarns significantly improves the UV protection factor of a garment [7]. The porosity and liquid transport efficiency differ significantly between fabric samples that have nearly identical weight, thickness, weave type and fabric count but with different fiber density [10]. Fabrics used in the summertime apparels often provide poor protection against UV because they are usually made from light–to-medium weight fabrics [15]. Abrasion plays also an important role on the fabric's quality because it is responsible for many effects that influence their surface and consequently, their appearance. Abrasion is responsible for many surface changes that occur on garments [8].

## 2. Experimental work

Quality improvement should begin at the design beginning and should continue through the production process. Therefore the System Design determining the suitable design parameters working levels is the first step before producing the fabrics. Parameters design aimed to determine the parameter levels that produce the best performance of the knitted fabric under study. Three yarns produced of three different polyester microfibers denier (M) (no. of microfibers in yarn cross section 96, 144, 288) were used, and blended with cotton yarns (C) on the feeders during knitting process. Therefore four yarns were used of nearly an equal count (36/1 Ne). The RKM and elongation ratio test results of these yarns using Uster Tensorapid are presented in Table (1).

**Table (1) RKM & Elongation test results for yarns**

| Yarn type& count | R.K.M | Elongation |
|---|---|---|
| Microfiber 288/150 | 34.01 | 16.6 |
| Microfiber 144/150 | 33.11 | 15.16 |
| Microfiber 96/150 | 36.96 | 19.30 |
| Cotton 36/1 Ne | 17.27 | 16.94 |

Jersey and rib fabrics were knitted with 3 different knitting machine setting producing three levels of fabric tightness (Three levels of knitting machine setting were monitored and controlled by changing cam setting and yarn tension system that can produce three levels of fabric tightness), and five feeding ratio of polyester (M) and cotton(C) yarns were used by ordering the yarns into the creel. It must be cleared that setting of the machine always occurred firstly with cotton yarns 100%. These factors and their levels are shown in Fig (1).

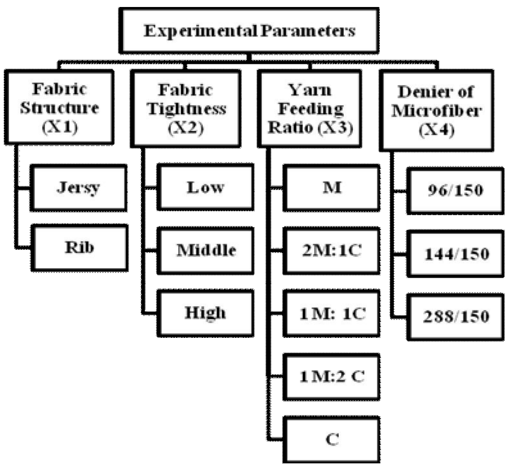


**Figure (1) Experimental Parameters levels**

Reaching the produced fabrics to the relaxation state was occurred by finishing process (washing, softness, squeezing and ironing).

The tested properties of the produced fabrics are: air permeability ($cm^3/cm^2/s$), (at 98 Pascal), thickness (0.001mm) and weight/$m^2$ ($gm/m^2$) of fabrics before and after wet relaxation, also the Ultraviolet Protection Factor (UPF) and abrasion resistance (number of cycles till a hole occurs using M235 Martindale Abrasion tester) (Sand paper 1000) of fabrics after wet relaxation, these were in accordance to the standard specifications ASTM D 737-75, ASTM D1777-64(75), ASTM D 3776-85, AS/NZS 4399:1996, ASTM D 4966 ,respectively. The UPF and abrasion resistance tests were carried after finishing.

## 3. RESULTS AND DISCUSSION

The research aimed to determine the optimum combination of the parameter levels and to know the contribution of each to the fabric quality. Therefore the tested results of the fabrics were measured and tabulated in Table (2). The method presented to evaluate the summer knitted fabric quality in this paper has been divided into three phases described below.

### 3.1 Phase I: Determining the effect of knitting parameters on summer fabric properties

Depending on the tested results, different properties can be determined and analyzed to estimate the effects of the knitting parameters on summer fabric properties before (G) and after wet relaxation (F).

**Table (2) The tested results and the calculated quality index of the produced fabrics**

| Sample No. | Fabric Structure X1 | Fabric Tightness* X2 | Feeding Ratio X3 | Denier of microfiber X4 | Air perme-ability ($cm^3/cm^2/s$) | | Weight/m2 Gm | | Thickness (0.01 mm) | | UPF | Abrasion (No. of Cycles) | Quality Index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | G | F | G | F | G | F | | | |
| 1 | Jersey | Low | M | 96 | 249 | 141 | 118 | 141 | 0.52 | 0.46 | 63 | 453 | 0.32 |
| 2 | Jersey | Low | 2M/1C | 144 | 258 | 161 | 112 | 123 | 0.45 | 0.38 | 39 | 169 | 0.28 |
| 3 | Jersey | Low | 1M/1C | 288 | 244 | 151 | 102 | 112 | 0.43 | 0.36 | 28 | 175 | 0.27 |
| 4 | Jersey | Low | 1M/2C | 96 | 255 | 140 | 109 | 117 | 0.48 | 0.41 | 29 | 143 | 0.23 |
| 5 | Jersey | Low | C | - | 266 | 141 | 111 | 158 | 0.44 | 0.56 | 23 | 47.5 | 0.21 |
| 6 | Jersey | Mid | M | 144 | 260 | 111 | 124 | 116 | 0.44 | 0.37 | 54 | 105 | 0.40 |
| 7 | Jersey | Mid | 2M/1C | 288 | 222 | 154 | 116 | 141 | 0.45 | 0.42 | 40 | 463 | 0.25 |
| 8 | Jersey | Mid | 1M/1C | 144 | 229 | 115 | 121 | 131 | 0.49 | 0.38 | 30 | 175 | 0.25 |
| 9 | Jersey | Mid | 1M/2C | 288 | 222 | 133 | 117 | 127 | 0.47 | 0.39 | 32 | 193 | 0.22 |
| 10 | Jersey | Mid | C | - | 219 | 203 | 127 | 172 | 0.53 | 0.49 | 23 | 218 | 0.19 |
| 11 | Jersey | High | M | 96 | 206 | 124 | 139 | 128 | 0.47 | 0.38 | 83 | 128 | 0.37 |
| 12 | Jersey | High | 2M/1C | 288 | 191 | 87 | 128 | 132 | 0.43 | 0.36 | 43 | 95 | 0.26 |
| 13 | Jersey | High | 1M/1C | 96 | 190 | 120 | 136 | 167 | 0.52 | 0.47 | 45 | 455 | 0.23 |
| 14 | Jersey | High | 1M/2C | 144 | 194 | 125 | 128 | 132 | 0.49 | 0.37 | 31 | 145 | 0.22 |
| 15 | Jersey | High | C | - | 217 | 170 | 131 | 181 | 0.52 | 0.56 | 35 | 108 | 0.21 |
| 16 | Rib | Low | M | 288 | 165 | 130 | 126 | 141 | 0.61 | 0.43 | 96 | 144 | 0.29 |
| 17 | Rib | Low | 2M/1C | 96 | 200 | 108 | 134 | 135 | 0.67 | 0.38 | 51 | 153 | 0.18 |
| 18 | Rib | Low | 1M/1C | 144 | 219 | 86 | 132 | 135 | 0.65 | 0.4 | 50 | 147 | 0.20 |
| 19 | Rib | Low | 1M/2C | 288 | 218 | 144 | 127 | 142 | 0.65 | 0.46 | 42 | 67.5 | 0.17 |
| 20 | Rib | Low | C | - | 232 | 136 | 125 | 169 | 0.7 | 0.56 | 29 | 77.5 | 0.15 |
| 21 | Rib | Mid | M | 96 | 187 | 168 | 151 | 141 | 8.93 | 0.61 | 94 | 60 | 0.32 |
| 22 | Rib | Mid | 2M/1C | 144 | 196 | 175 | 140 | 137 | 0.67 | 0.57 | 62 | 73.8 | 0.25 |
| 23 | Rib | Mid | 1M/1C | 96 | 200 | 171 | 139 | 142 | 0.66 | 0.57 | 54 | 52.5 | 0.20 |
| 24 | Rib | Mid | 1M/2C | 144 | 200 | 175 | 138 | 140 | 0.65 | 0.58 | 47 | 57.5 | 0.18 |
| 25 | Rib | Mid | C | - | 205 | 132 | 133 | 192 | 0.68 | 0.56 | 42 | 92.5 | 0.15 |
| 26 | Rib | High | M | 288 | 234 | 141 | 145 | 155 | 0.53 | 0.73 | 83 | 333 | 0.35 |
| 27 | Rib | High | 2M/1C | 144 | 216 | 151 | 155 | 144 | 0.6 | 0.56 | 60 | 166 | 0.21 |
| 28 | Rib | High | 1M/1C | 288 | 196 | 166 | 146 | 150 | 0.61 | 0.57 | 49 | 91.3 | 0.17 |
| 29 | Rib | High | 1M/2C | 96 | 194 | 149 | 152 | 147 | 0.62 | 0.56 | 46 | 72.5 | 0.16 |
| 30 | Rib | High | C | - | 175 | 95 | 146 | 184 | 0.63 | 0.54 | 42 | 72.5 | 0.14 |

*** Machine setting levels producing three fabric tightness (Low, Middle, High )**
**G: Grey fabrics**
**F: Fabrics after wet relaxation**

**Feeding ratio%: M= 100% Microfiber, 2M/1C= 67%:33%, Microfiber/ Cotton, 1M/1C= 50%:50% Microfiber/ Cotton, 1M/2C= 33%: 67% Microfiber/ Cotton, and C=100% Cotton yarns**

Regression equations were proposed for the results and could be determined in the equations from (1) to (8) which are demonstrated with R-square of (0.74 to 0.95).

Air Permeability G= $314-76.9*X_1 -30.6*X_2+15.5*X_3+25.6*X_1*X_2-7.48*X_2*X_3$ $R^2$=0.75 (1)

Air Permeability F= $71.2 + 28.8*X_1 + 12.6*X_2 + 29.2*X_3 – 8.1*X_2*X_3– 3.52* X_3^2$ $R^2$=0.74 (2)

Weight/ m2 G= $99.5+14.5*X_1+10.5*X_2 -2.3*X_3 -6.4*X_4+2.2*X2*X_4$ $R^2$=0.95(3)

Weight/ m2 F= $165.3 – 10.1*X_1 – 27.1*X_3- 7.74*X_4+ 2.46*X_3^2+ 10.0*X_1*X_2+ 5.2*X_1*X_3 + 1.87*X_3*X_4$ $R^2$= 0.92(4)

Thickness*100 G= $29.0+ 23.7*X_1+4.4X_2-1.0*X_3-5.3 *X_4 -3.4*X_1*X_2 +1.0*X_3*X_4$ $R^2$=0.95(5)

Thickness*100 F= $46.8 + 17.3*X_1 - 8.1*X_3 – 10.4*X_4 + 2.49*X_3*X_4+ 0.56*X_3^2$ $R^2$=0.95 (6)

UPF F= $71+ 10*X_1+ 8.85*X_2 - 30*X_3 + 4.06X1*X_4 - 3.37*X_2*X_4+ 3.21*X_3^2$ $R^2$=0.92 (7)

Abrasion F= $807 – 215*X_1 - 254*X_3 + 37.2*X_1*X_3 + 24.4*X_3^2$ $R^2$=0.77 (8)

*Where:*

G: Grey fabrics, and F: Fabrics after wet relaxation

The results of fabric properties are also presented in Figures from (2) to (9). These figures help to show how fabric quality can be affected by different parameters under study before and after wet relaxation. It is obvious that almost all factors affect the fabric quality. Also the blending ratio significantly affects the fabric quality.

### 3.1.1 The effect of parameters on Air permeability

From equations (1) and (2), and Figures from (2) to (5) for air permeability before and after wet relaxation the following notes could be concluded:

- Shrinkage of knitted fabrics after wet relaxation decreases its air permeability especially for Jersey fabrics produced from cotton yarns.
- Increasing fabric tightness by machine setting also decreased the air permeability
- Rib finished fabrics have higher air permeability than Jersey fabrics, while Rib grey fabrics have lower air permeability than Jersey fabrics.
- Blended fabrics tend to permit more air to pass through it, as compared to 100% cotton fabrics produced with same machine setting.

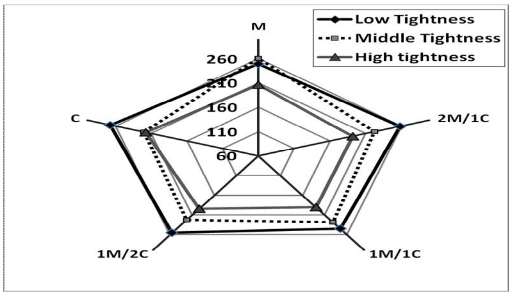


**Figure (2) Air permeability of Jersey Grey fabrics**

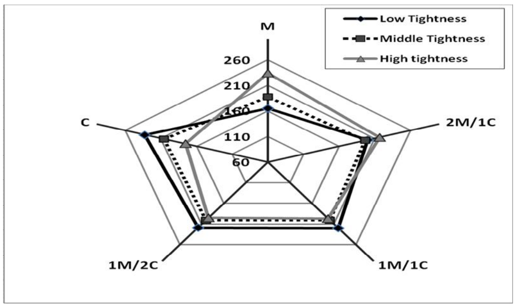


**Figure (3) Air permeability of Rib Grey fabrics**

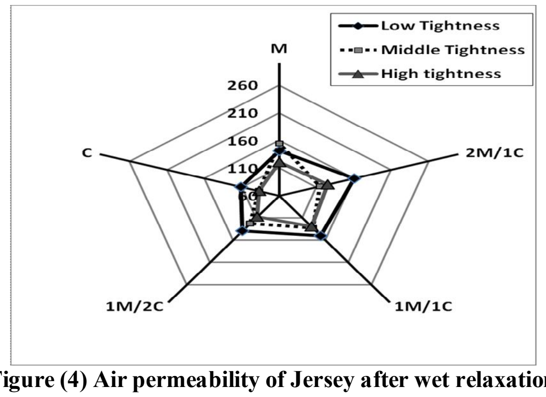


**Figure (4) Air permeability of Jersey after wet relaxation**

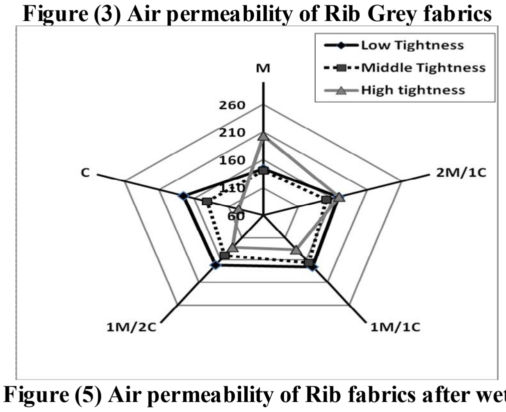


**Figure (5) Air permeability of Rib fabrics after wet relaxation**

### 3.1.2 The effect of factors on fabric weight/m$^2$

From equations (3) and (4), and Figures from (6) to (9) for weight/m$^2$ before and after wet relaxation it could be concluded the following notes:

- Increasing fabric tightness by machine setting increased the weight of the fabric
- After wet relaxation, the weight of fabrics increased.

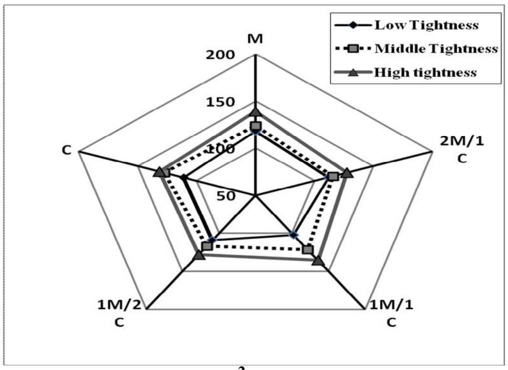


**Figure (6) Weight/m$^2$ of Grey Jersey fabrics**

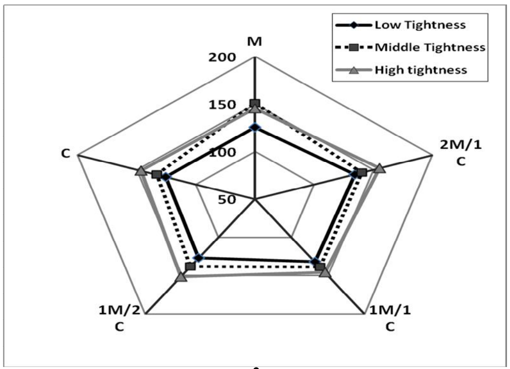


**Figure (7) Weight/m$^2$ of Grey Rib fabrics**

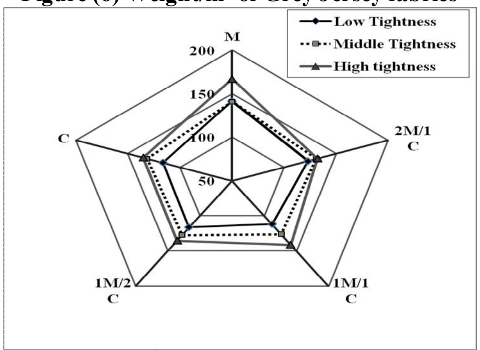


**Figure (8) Weight/m$^2$ of Jersey fabrics after wet relaxation**

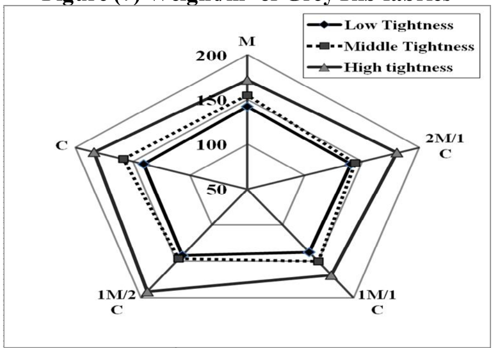


**Figure (9) Weight/m$^2$ of Rib fabrics after wet relaxation**

### 3.1.3 The effect of factors on fabric thickness

From equations (5) and (6), and Figures from (10) to (13) for thickness before and after wet relaxation it could be concluded the following notes:

- The thickness was increased by increasing the fabric tightness
- Using rib structure increased the fabric thickness
- Thicker denier of microfiber into yarns increased fabric thickness
- Wet relaxation led to more fabric shrinkage
-

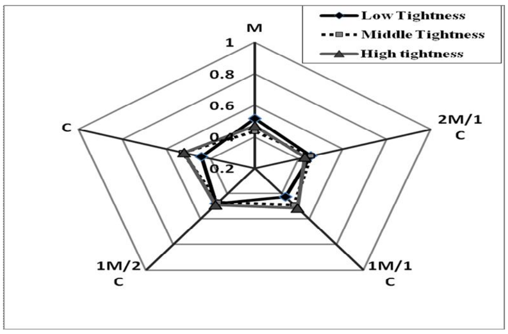


**Figure 10 Thickness of Grey Jersey fabrics**

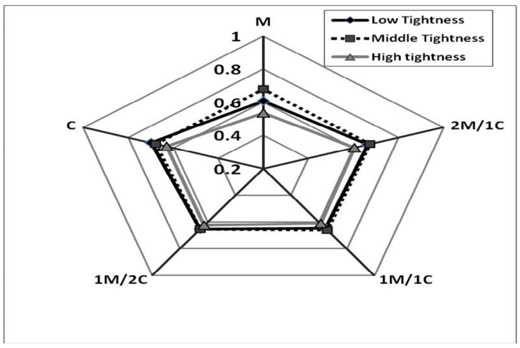


**Figure 11 Thickness of Grey Rib fabrics**

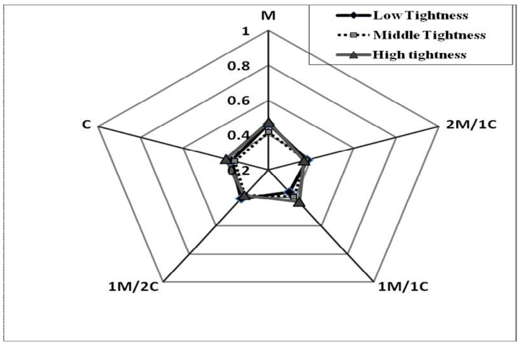


**Figure 12 Thickness of Jersey fabrics after wet relaxation**

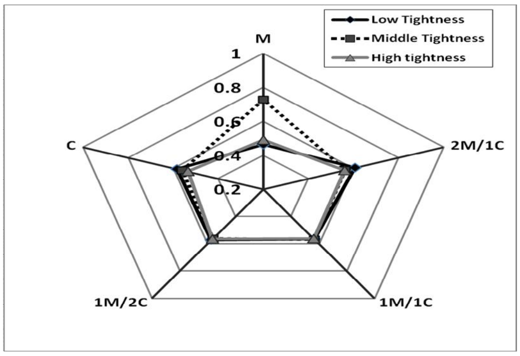


**Figure 13 Thickness of Rib fabrics after wet relaxation**

### 3.1.4 The effect of factors on UPF

The evaluation of the protection of the knitted fabric against UV radiation is shown in Table (2) by the UPF values according to AS/NZS 4399: 1996. From equation (7) and Figures (14) & (15) for UPF after wet relaxation the following notes could be concluded:

- As expected, Fabrics of microfibers have the highest UPF, however similar fabrics of cotton yarns have the lowest UPF
- In general, fabrics made of tight construction have the best protects skin against the sun, since it decreased spacing between yarns
- Rib finished fabrics have higher UPF than Jersey fabrics

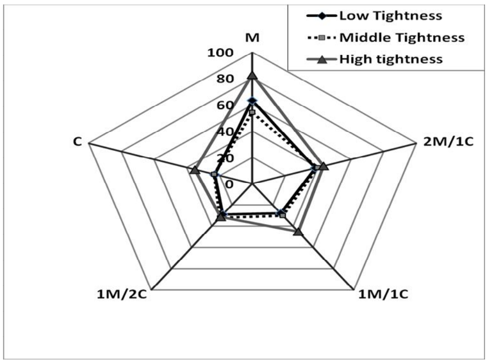


**Figure (14) UPF of Jersey fabrics**

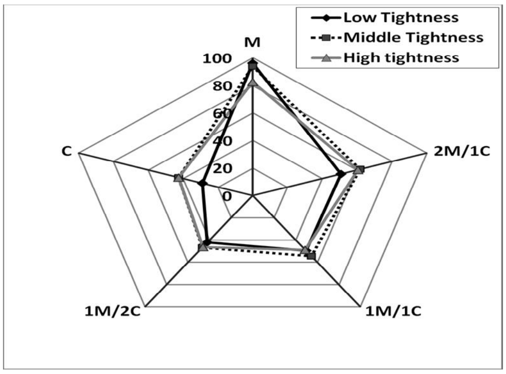


**Figure (15) UPF of Rib fabrics**

### 3.1.5 The effect of factors on fabric abrasion

From equations (8) and Figures (16) & (17) for abrasion after wet relaxation the following notes could be concluded:

- Increasing the ratio of microfibers increased the resistance of abrasion for all fabrics, fabrics of microfibers have the highest resistance to abrasion, however similar fabrics of cotton yarns have the lowest one have
- Jersey finished fabrics have higher UPF than Rib fabrics

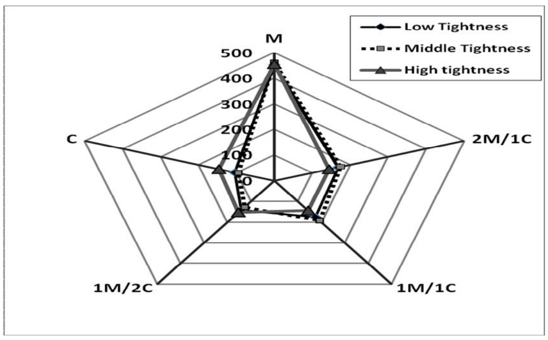


**Figure (16) Abrasion resistance of Jersey fabric**

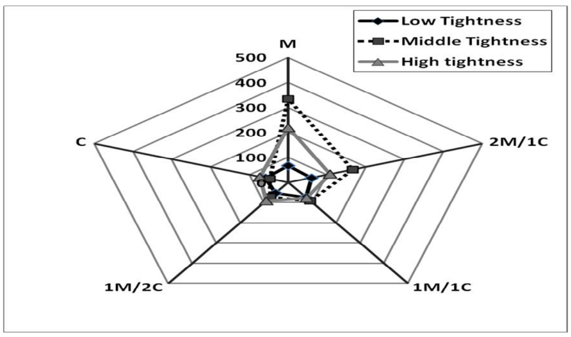


**Figure (17) Abrasion resistance of Rib fabric**

From the previous relations, it was observed that changing the yarns at the same machine setting change the fabric construction, weight that affect on fabric properties. The reason for the changing of yarn feeding ratio of microfibers, cotton, fabrics can be attributed to the difference in properties of these yarns, due to the fibre length, diameter, density and surface. The feeding ratio of P and C yarns% in knitting ($X_3$) played an important role in all properties where increasing microfiber ratio in the fabrics increased the UPF, resistance of abrasion, thickness and weight of fabrics; however fabrics made of cotton yarns, light weight, less thickness are suitable for summer requirements.

### 3.2 Phase II. Establishing fabric quality index

For carrying out the complete optimum analysis, a radar area method is used to analyze the average result of finished fabric properties.

The radar values of properties coefficient were determined according to summer fabric requirements as follows:

R value= minimum/ observed value for (Weight, Thickness) where is minimum is better

R value= observed / maximum value for (UV, Air, Abrasion) where is maximum is better

This presented index is possible to be calculated on the base of the area under the radar curve which could be calculated as follows:

Radar Area (R) = 0.5× (sin (360/5)) × ((UV × Air )+ (Air × W) + (W × T) + (T× Ab) + (Ab × UV))

Where: UV=ultraviolet protection factor, A= air permeability, W= fabric weight/m2, T= thickness, and Ab= abrasion resistance

The radar areas of experimental designs R could be considered as quality index. Fabrics quality indexes are shown in Table (2). These results were presented in Figure (18)

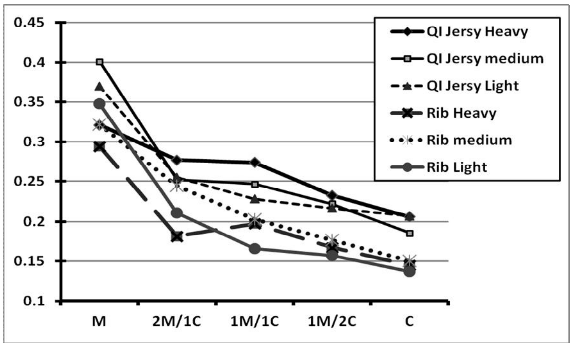


**Figure (18) Quality Index of fabrics**

### 3.3 Phase III: Determining the optimal knitting condition response to fabric quality index

The objective of analysis is to determine the most optimum set of the operating conditions by variation of the influencing factors within the result. The highest possible performance is highlighted in Table (2) by determining the optimum combination of design factors.

This method helps to determine the possible combinations of factors and to identify the best combination. A better and more-detailed understanding about the fictionalization of fabric using Microfiber/cotton yarns could be obtaining.

## 4. Conclusion

Summer fabric quality should meet the criteria of protection against sun, appearance and comfort in wearing. Their behavior depends upon their mechanical and physical properties but there are no standards available that could be used as a guide in summer fabric quality evaluation. However, the paper presents a method of predicting summer knitted fabric quality of cotton and microfiber yarns. The method presented to evaluate the summer knitted fabric quality is based on a precisely designed control system, aimed to define the important elements for fabric properties.

They represent 4 key factors of technical knitting parameters include blending ratio, machine setting, denier of polyester fibers, and fabric structure. Parameter design aims to determine the factor levels that produce the best performance of the knitted fabric under study.

To reach this goal, the first step included subjective evaluation of fabric properties in the course of manufacturing, as well as the additional evaluation. Properties of fabrics included air permeability, UPF, abrasion resistance, weight, and thickness of fabrics were determined for all the analyzed fabrics using regression analysis, and correlations were established among the individual technical knitting parameters and fabric properties.

The fabric quality index was determined by measuring the radar area in the next step. This correlation is essential, since it constitutes previous knowledge in the development of the system for predicting summer fabric quality. And the third step was determining the knitting condition which produced fabrics with the highest quality indexes that could be a developing step in fabric designing for predicting summer fabrics quality.

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