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EFFECT OF SELECTED MULTI LAYERED FABRICS CONSTRUCTION ELEMENTS ON THERMAL RESISTANCE OF DUVETS

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ABSTRACT

Multi-layered duvets fabrics are characterized by its light weight and the ability to provide warmth. There are many types of duvets that suit different seasons and climates. The degree of warmth achieved by the duvet and which is directly connected to the thermo physiological comfort characteristics of fabrics is rated through the TOG (thermal overall grade).The aim of this paper was to study the fabric construction elements that affect the overall warmth of the multilayered duvets. Accordingly, nine samples were produced for studying thermal resistance, wherethe warp and weft yarns of all samples were made of cotton fibers. In addition, weft yarns, used for wadded, were Polyester, Polypropylene, and Acrylic. Moreover, the ratio of the number of waddedwefts to the number of face and back weft yarns were 33.3%, 50%, and 60%. The study showedthat the thermal resistance is influenced by specific density and the morphology of wadded wefts.

Key Words: Comfort, Thermo Physiological Comfort, TOG, Duvet, Multi Layered Fabric

I. INTRODUCTION

Interior textiles are defined as a type of textiles used in several applications; such as tapestries, wall coverings, tablecloths, carpets, rugs, floor coverings, upholstery fabrics, bed sheets, duvets, window blinds and curtains to towels and mattresses. When selecting fabrics for interior application, the decision should involve not only aesthetic aspects but also the fabric structure and composition. Principally multi layered fabrics which used for interior textiles such as duvets and mattresses. Where multi-layered fabrics consist of different layers of the fabrics which have the ability to complement and maximize the essential comfort properties [1]. Duvets are the most Multi-layered Fabrics using for warming due to existence a lot of materials achieved warming with light weight. As a result of industrial development in Bedding Fabrics, there is a possibility for manufacturing Duvets with different degrees of warming According to the climate conditions surrounding us[2].

1.1 Thermal Performance of multi layered fabrics

Thermo physiological comfort characteristics of fabrics used in the manufacturing of inner and outer layer fabrics[3]. Manufacturers rate the performance of their duvets in tog (thermal overall grade), Tog is a unit of thermal resistance used to measure the power of insulation of a fabric, garment, quilt, etc. Where the thermal resistance (TOG value) of a product is ascertained by measuring the temperature drop across the test specimen

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and comparing this with the performance of a known material under the same conditions a measurement of thermal insulation[4]. This enables the purchaser to select a duvet appropriate to the season: the higher the tog rating, the warmer the duvet.

A few manufacturers have marketed combined duvet sets, one of approximately 4.5 tog and one of approximately 9.5 tog. The light-weight one is for summer and the medium one for autumn; snapped together, 14 togs is designed for winter[2].

The tog-value of an article is equal to ten times the temperature difference between its two faces, in degrees celsius, when the flow of heat across it is equal to one *watt/*m^2.The TOG system for describing the thermal insulation properties of textile products originated at the Shirley Institute in the 1960's and the Shirley Tog meter was devised for measuring insulation values. Today the system is universally used and is particularly familiar in connection with rating of duvets[4]

Figure (1) Tog Values of Duvets versus Temperature

1.2 Thermal Insulation Materials

- Natural fibers have lower thermal conductivity than synthetic fibres in the dry state but they absorb around 8-13%moisture and such a high moisture content increase their thermal conductivity on the lower side[5].
- Category of fibers which provide thermal insulation entraps as much air as possible and has low compressibility. High resilience and high bulk. Among synthetic fibres, Polyester and Polypropylene have thermal conductivity on the lower side. Main factors that govern thermal insulation value of fabric are the thickness which determines the degree of insulation provided by the clothing, the construction – open structure has lower thermal insulation due to high convective losses, and the bulk density which influences the amount of air entrapped in the structure[6],[7]

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1.4 Experimental work

In this study 9 samples were studied for thermal insulation. The warp and weft yarns of all samples were made of cotton fibers. In addition, weft yarns, used for wadded, were Polyester, Polypropylene, and Acrylic. Moreover, the ratio of the number of wadded weftsto the number of face and back weft yarns were 33.3%, 50%, and 60%. The complete specification of samples under study is tabulated in table (1).

Table (1): Samples specifications

No.	Warp Density/cm	Weft Density /cm	wadded Wefts Materials	Wefts Arrangement	The proportion of the wadded wefts (%)
1	36	50	Polyester	1Face:1Back:1wadded	33.3
2	36	50	Polyester	1Face:1Back:2 wadded	50
3	36	50	Polyester	1Face:1Back:3 wadded	60
4	36	50	Polypropylene	1Face:1Back:1 wadded	33.3
5	36	50	Polypropylene	1Face:1Back:2 wadded	50
6	36	50	Polypropylene	1Face:1Back:3 wadded	60
7	36	50	Acrylic	1Face:1Back:1 wadded	33.3
8	36	50	Acrylic	1Face:1Back:2 wadded	50
9	36	50	Acrylic	1Face:1Back:3 wadded	60

II. STRUCTURES WEAVING USED

2.1 First design (Samples1, 4 and7)

The following structures are used to produce the research samples number (1, 4 and 7) whereas the arrangement of wefts for these samples is (1 face weft: 1 back weft: 1 wadded weft), that means the proportion of the wadding wefts is 33.3% of the produced samples wefts. Plain double weave with stitching for Face and Back layers is used as shown in figures (2), (3) and (4) figure (5) simulation and figure (6) card design.

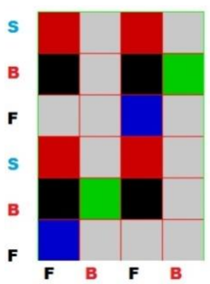
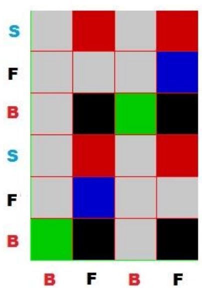


Figure (2): first colour



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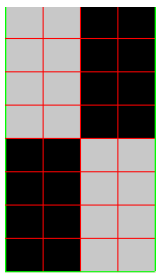

Figure (4): third colour

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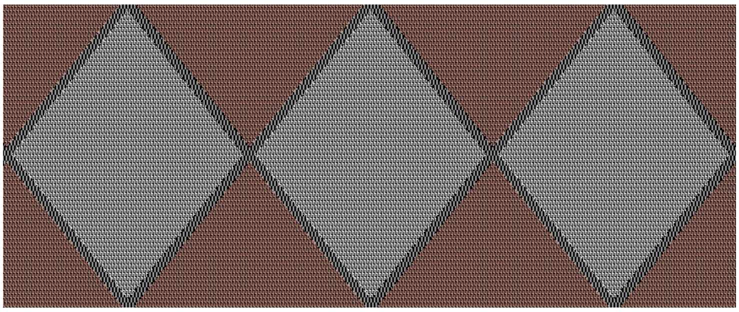


Figure (5): simulation

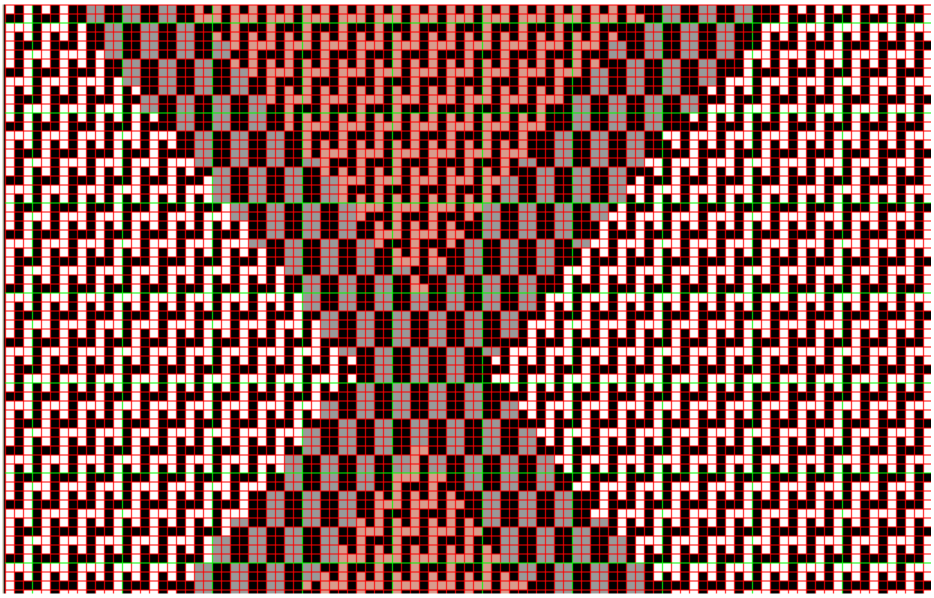
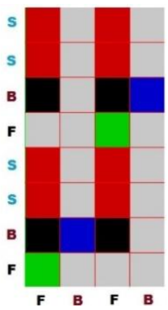
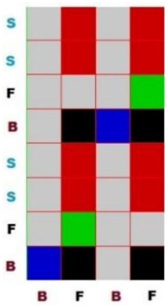


Figure (6): card design

2.2 Second design (samples2, 5, and 8)

The following structures are used to produce the research samples number (2, 5, and8) whereas the arrangement of wefts for these samples is (1 face weft: 1 back weft: 2 wadded weft), that means the proportion of the wadding wefts is 50% of the produced samples wefts. Plain double weave with stitching for face and back layers is used as shown in figures (7), (8) and (9), figure (10) simulation and figure (11) card design.





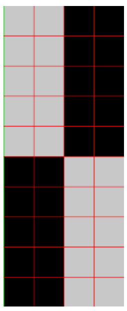


Figure (7) first colour **Figure (8) second colour** **Figure (9) third colour**

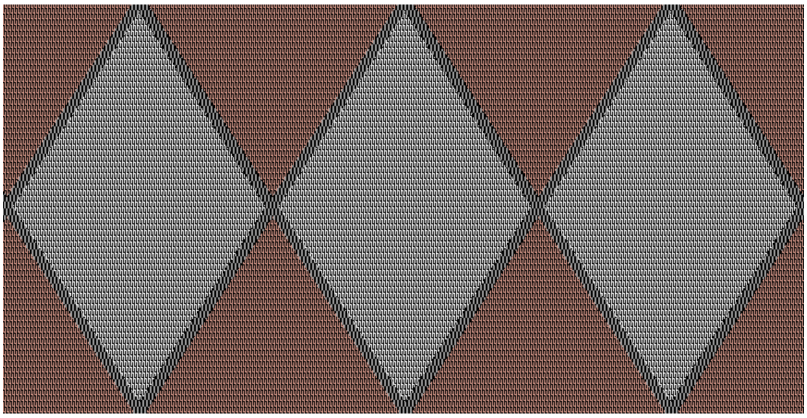


Figure (10) simulation

Figure (11): card design

2.3 Third design (Samples3, 6, and9)

The following structures are used to produce the research samples number (3, 6, and 9) whereas the arrangement of wefts for these samples is (1 face weft: 1 back weft: 3 wadded weft), that means the proportion of the wadding wefts is 60% of the produced samples wefts. Plain double weave with stitching for face and back layers is used as shown in figures (12), (13) and (14) ,figure (15) simulation and figure (16) card design.

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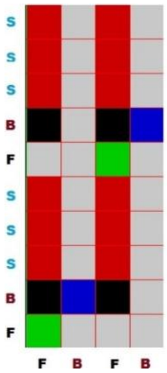

Figure (12) first colour

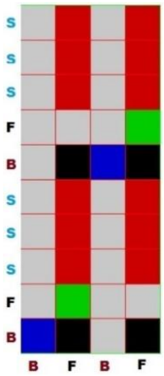

Figure (13) second colour

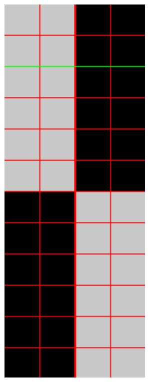

Figure (14) third colour

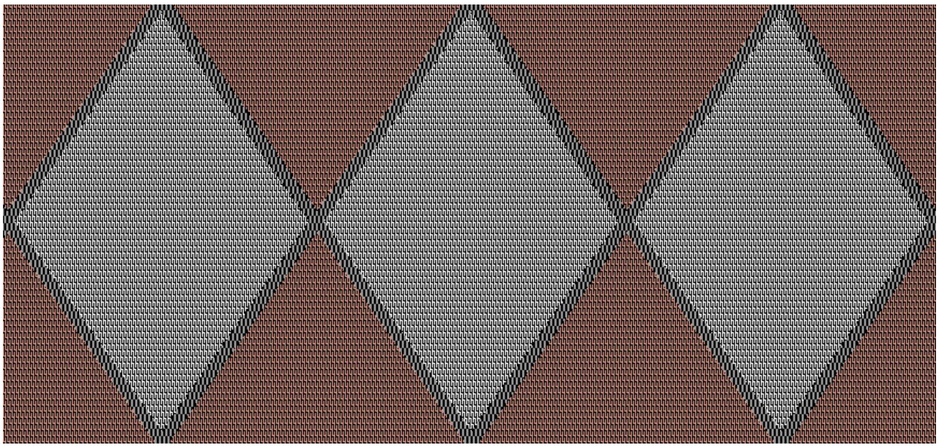

Figure (15) simulation

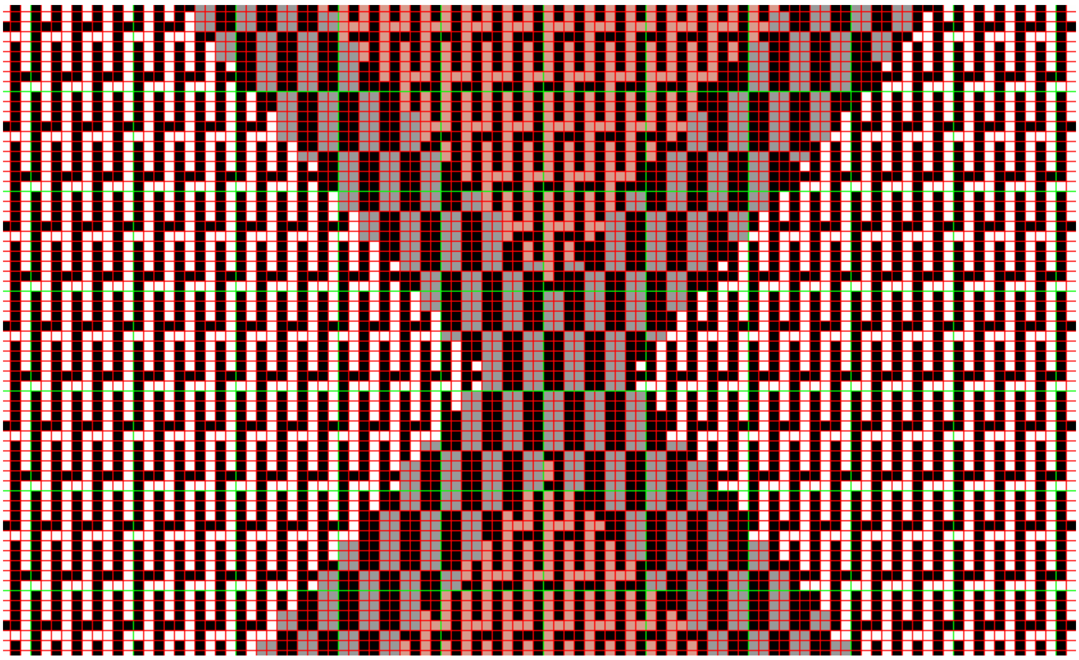

Figure (16) card design

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Samples were tested for fabric weight[8], fabric thickness[9],fabric air permeability[10], and fabric thermal resistance[11].

A permeates apparatus (skin model), was used to measure fabric thermal resistance according to (ISO11092:2014) standard measurement of thermal and water vapour resistance.

III. RESULTS AND DISCUSSION

The results of tests are listed in the table (2).

Table (2) the tests results

no.	Wadded wefts Materials	The proportion of the wadded Wefts	Fabric Weight (gm/m2)	Fabric Thickness (mm)	Air Permeability ($cm^3/cm^2/sec$)	Thermal Resistance $m^2k..w^{-1}$
1	Polyester	33.3%	642.1	1.9	24.4	7.4
2		50%	771.9	2.3	43.3	12.5
3		60%	840.2	2.7	32.7	14.6
4	Polypropylene	33.3%	642.7	3.9	25.7	47.2
5		50%	767.5	5.5	31.6	71.1
6		60%	838.3	6.9	29	89.3
7	Acrylic	33.3%	659.4	3.4	24.3	38.2
8		50%	766.2	4.8	38.9	79.9
9		60%	830.3	6.1	33.6	96.3

Moreover, all results were grouped according to wadded wefts materials, whereas the warp and weft materials were cotton.

3.1 The effect of wadded wefts on fabric weight

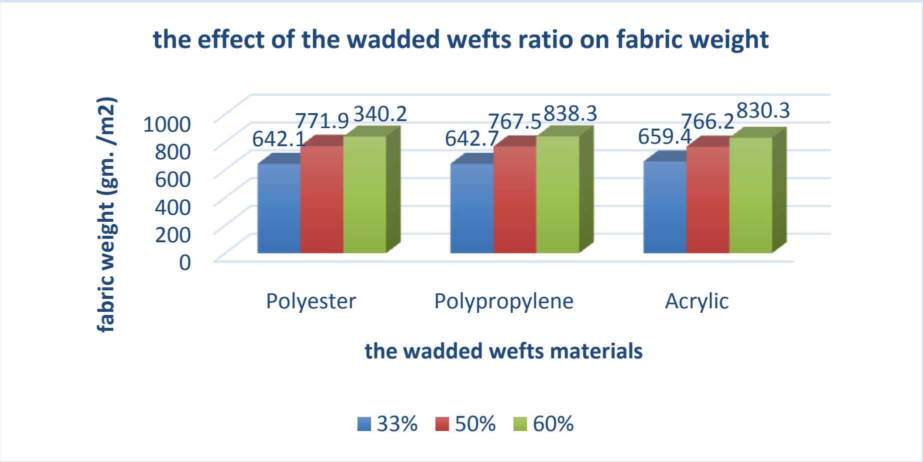

Figure (17) the effect of the wadded wefts ratio on fabric weight

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Regression equations obtained from statistical analysis of the weight test results, as shown in annexure (A), figs. (A-1), (A-2) and (A-3) showed that there was a strong correlation coefficient between wadded weft ratios and fabric weight.

As mentioned above, and from table (2) and fig. (17). the ratio of wadded wefts (60%) recorded the highest weight values for all materials. Moreover, there was a positive relationship between the ratio of the wadded wefts and the fabric weight. In addition, the variance of wadded wefts materials affected sample weights. This can be explained by the specific density (gm/cm^3) of tested samples which translates into a direct proportional relation between specific density and weight as specific density =$\frac{weight}{volume}$. And as Polyester fiber has a greater specific density (1.23-1.38 gm/cm^3), when compared to Acrylic (1.16-1.18 gm/cm^3) and Polypropylene (0.9-0.91 gm/cm^3) respectively, therefore Polyester scored a higher weight.

3.2 The effect of wadded wefts on fabric thickness

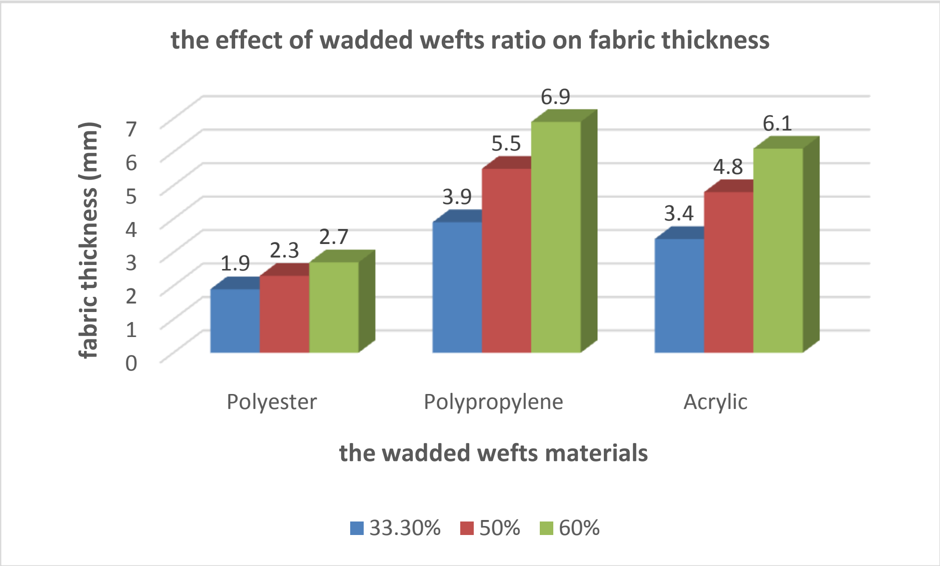

Figure (18) the effect of the wadded wefts ratio on fabric Thickness

Statistical analysis of thickness test results, as shown in annexure (A), figs. (A-4), (A-5) and (A-6), proved that there was a strong correlation coefficient between wadded wefts ratios and fabric thickness.

In addition, it was illustrated from table (2) and fig. (18) that the ratio of the wadded wefts (60%) recorded the highest thickness values among all materials.

Results have also shown that there was a positive relationship between the ratio of the wadded wefts and the fabric thickness. On the other hand, the different types of wadded wefts materials affected the thickness of samples. This could be explained by reviewing the specific density ($\frac{weight}{volume}$ gm/cm^3) of each material. As mentioned earlier, specific density of Polypropylene was (0.9-0.91 gm/cm^3) which is the lowest specific density when compared to Acrylic and Polyester.

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The results show that Polypropylene scored the highest fabric thickness. The reason for that can be explained by reviewing the specific density value for Polypropylene which is the lowest when compared to the other two samples. The relation between sample thickness and specific density can be explained by reviewing the law governing specific density which is weight divided by volume, where volume = length*width*height. Assuming length and width are equal for all sample the difference will be in sample height which in turn is a direct indication for thickness. Consequently the smallest specific density of Polypropylene led to highest thickness among all samples.

3.3 The effect of wadded wefts on Air Permeability

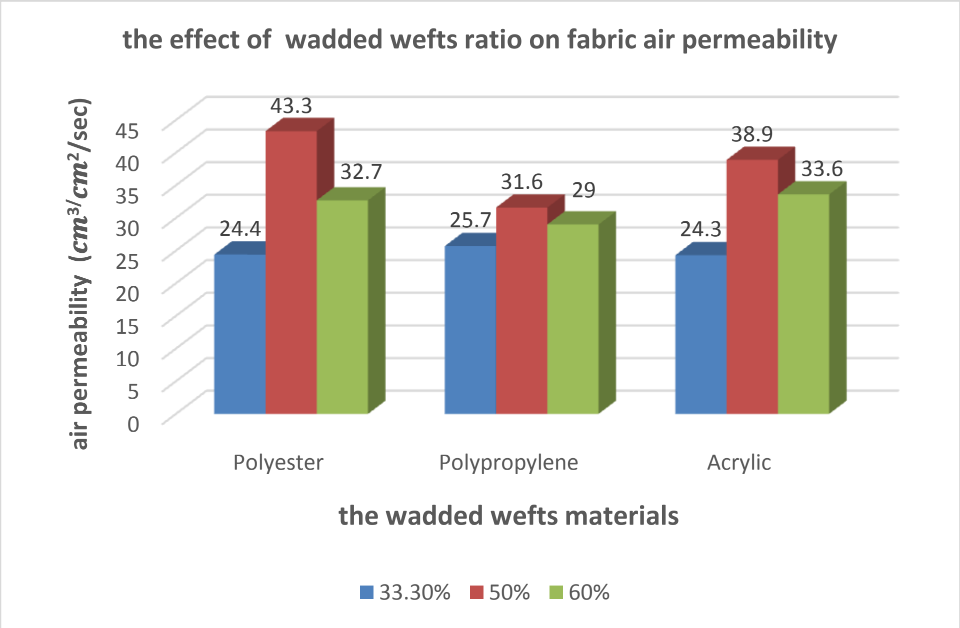

Figure (19) the effect of the wadded wefts ratio on fabric air permeability

According to the statistical analysis of the air permeability test results, the relationship between fabric air permeability and ratio of the wadded wefts materials is a non- linear correlation as shown in annexure (A). Furthermore, only a weak correlation could be established between fabric air permeability and the wadded wefts ratio (R^2 = 0.01 to 0.49) as shown in figs. (A-7) and (A-8) for Polyester and Polypropylene.

Additionally, a moderate correlation could be established between fabric air permeability and the wadded wefts ratio (R^2 =0.50 to 0.69) as shown in fig. (A-9) for Acrylic.

Moreover, 50% wadded wefts recorded the highest air permeability values when compared to all other materials as shown in table (2) and fig. (19). On the other hand the 33.3% and 60% wadded achieved the lowest air permeability values.

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3.4 The effect of wadded wefts on thermal Resistance

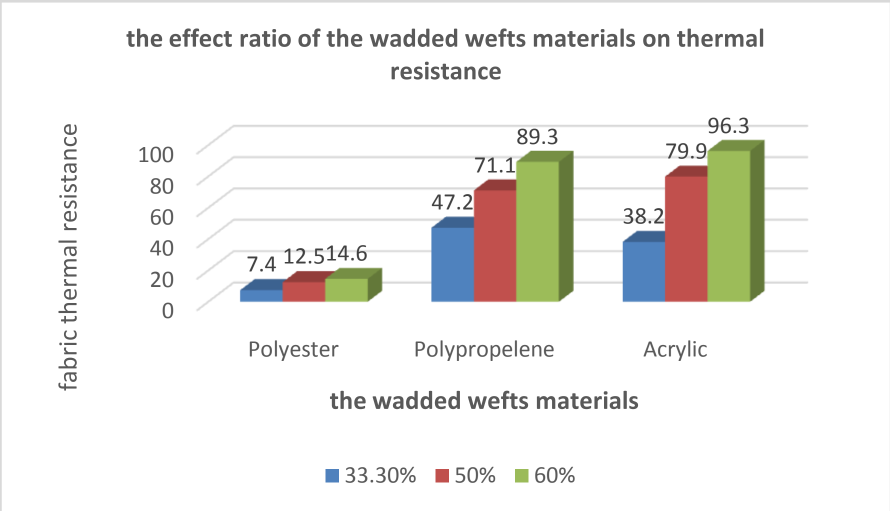

Figure (20) the effect of the wadded wefts materials on fabric thermal resistance

Statistical analysis of the thermal resistance results for different wadded weft ratiosshowed that there is a strong correlation coefficientbetween fabric thermal resistance and the wadded weft ratios (R^2 = 0.70 to 0.99) as shown in figs (A-10), (A-11) and (A-12), annexure (A).

And by referring to table (2) and fig. (20), the ratio of (60%) of the wadded wefts for all materials recorded the highest thermal resistance values.

Furthermore, the highest thermal resistance values were achieved by using Acrylic and Polypropylene wadded wefts at a ratio of 60% when were compared with Polyester at the same ratio. The superior thermal resistance was affected by the bulky morphology and air gabs of Acrylic and Polypropylene wadded weft yarns respectively

As mentioned in the introduction of this study, manufacturers determined the thermal resistance values of their duvets in tog (thermal overall grade). This enables the purchaser to select a duvet appropriate to the season: the higher the tog rating, the warmer the duvet.

$$\text{Tog} = 0.1\boldsymbol{k}.\boldsymbol{m^2}.\boldsymbol{w^{-1}}$$

Table (3) shows the thermal resistance results test by $(mk.m^2.w^{-1})$ and (TOG), in addition to the duvet performance according to the tog value.

Table (3) the results of thermal resistance $(\boldsymbol{mk.m^2.w^{-1}})$& (TOG)

Ratio	Material	Thermal Resistance $(mk.m^2.w^{-1})$	Thermal Resistance (TOG)	Duvet Performance
33.3%	Polyester	7.4	0.7	-
	Polypropylene	47.2	4.7	Summer

	Acrylic	38.2	3.8	Summer
50%	Polyester	12.5	1.2	-
	Polypropylene	71.1	7.1	Spring
	Acrylic	79.9	7.9	Spring- Autumn
60%	Polyester	14.6	1.4	-
	Polypropylene	89.3	8.9	Spring- Autumn
	Acrylic	96.3	9.6	Spring- Autumn

IV. CONCLUSION

In this study ninemulti layered fabrics varying in wadded wefts type (Polyester, Polypropylene, and Acrylic) were tested. Moreover, the ratio of the number of weft waddings to the number of face and back weft yarns were 33.3%, 50%, and 60%.

After statistically analysing the data, the results can be summarizedas follows:

1. Wadded wefts ratio of (60%) recorded the highest weight and thickness values for all materials. Moreover Polypropylene scored the highest fabric thickness at this category.
2. Samples with 50% wadded wefts recorded the highest air permeability values when compared to all other materials.
3. The thermal resistance was affected by bulkymorphology and air gabs of Acrylic and Polypropylene wadded weft yarns respectively.In addition, the highest thermal resistance values were achieved by using Acrylic and Polypropylene wadded wefts at a ratio of 60% when were compared with Polyester at the same ratio.

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