Research Article

Optimization of Thermal Comfort Properties in Duvets by Thermal Resistance Measurements in Home Textile Products

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(First received September 15, 2022 and in final form December 09, 2022)

Reference: Durmuş M., Demir R., Kahraman F. B., Ekinci E., Güneşoğlu C., Sancak E. Optimization of Thermal Comfort Properties in Duvets by Thermal Resistance Measurements in Home Textile Products. The European Journal of Research and Development,2(4), 81-89.

Abstract

Home textiles have many functions, as well as their aesthetic features for the decoration of homes, that will make people's lives more comfortable. In other words, home textile products are textiles that increase the quality of life and satisfy the daily essentials of individuals for a healthy sleep. It is observed that the home textile industry is becoming exceedingly competitive and products that provide customer satisfaction and offer quality are generally preferred in the global market. The objective of this study is to determine the thermal comfort properties of duvets by making thermal resistance measurements in home textile products and to reveal the effects of properties on sleep quality. In line with this objective, the air and heat permeability of the duvets were measured with the TOG (Thermal Overall Grade) value. As a result of the measurements, the effects of the fiber type and thickness of the filling material in the duvet layers, the fiber type and density of the fabrics and interlining on the TOG values were observed. According to the high or low TOG value, the thermal resistance properties of the duvets were determined with the *effect of layer, thickness and material. As a result of this study, the fabric, interlining and filling materials in the duvet layers were standardized according to the TOG values obtained.*

Keywords: *Home Textile, Duvet, TOG, Thermal Resistance, Thermal Overall Grade*

1. Introduction

Sleep is very significant for both mental and physical health of people. Just as food and water are a necessity for a healthy life, sleep is just as important and inevitable. But research shows that 40% of people are faced with insufficient sleep. Khalladi et al. (2019) point out there are many factors that affect insomnia and sleep quality. These factors can be listed as age, gender, income status, alcohol use, etc. In addition, insomnia cause many disorder, such as cancer, cardiovascular diseases, loss of performance, memory loss according to Loft et al. (2014). Therefore, providing the necessary conditions for a good sleep will increase the quality of sleep. The compatibility of the pillow and mattress with the person's anthropology, thermal comfort, light intensity should be considered in the optimization of the ambient conditions. Thermal comfort is very important for the quality of human sleep as stated by Bokel et al. (2018). Providing thermal comfort during sleep, along with the human body physiology tends to feel comfortable, so the cycles that occur during sleep are idealized and result in quality sleep. The reason for having difficulty falling asleep in hot weather and waking up frequently during the night is that the ambient conditions do not provide sufficient thermal comfort.

Morris (1953), in the study on the thermal properties of fabrics and thermal comfort, focused on the fabric's effectiveness in maintaining the normal temperature of the human body under balanced conditions, the property felt by the person's internal reaction when touching the fabric, and the fabric's ability to reduce the effect of sudden changes in atmospheric temperature and humidity on the human body. It was concluded that thermal insulation in textile fabrics primarily depends on the amount of stagnant air contained in the fabric and yarn. Another result is that fabric thickness is the most important factor of thermal insulation of textiles, but if the fabrics are of the same thickness, the lower density fabric shows greater thermal insulation.

Clulow (1978) investigated thermal resistance values on the ability to retain heat, which is one of the comfort parameters. Clulow expressed the thermal resistance in "TOG" unit. In this study on thermal resistance values, Clulow (1978) examined the thermal values of existing textile products to determine the most suitable fabrics according to the ambient conditions to be used.

The aim of Frydrych et al. (2003) study is to determine how different materials and different finishing processes affect thermal comfort properties. According to the results obtained, the heat transfer coefficient increases linearly with the PES ratio. 100% CO fabric has the best heat transfer coefficient, handle + anti-crease finish. The handling process improves the thermal properties. The fabric with the highest density has a higher heat transfer coefficient than the other density.

This study focused on the experimental study on the determination of thermal resistance measurements in home textile products and thermal comfort properties in duvets by using such different fabrics, fillings, filling amounts, weaving density.

2. Materials and Methods

In this study, 22 different type of duvets were examined in different filling materials, filling amounts, fabric types and fabric weaving density. The duvet specifications are given in the Table 1.

Table 1: Specifications of duvets

Sample	Fill Material	Fill Amount
1	Siliconized Fiber	130 g/m²
2	Siliconized Fiber	300 g/m²
3	Wool Fiber	400 g/m²
4	Cotton Fiber	300 g/m²
5	Siliconized Fiber	300 g/m²
6	Siliconized Fiber	300 g/m²
7	Siliconized Fiber	200 g/m²
8	Siliconized Fiber	200 g/m²
9	Siliconized Fiber	150 g/m²
10	Siliconized Fiber	200 g/m²
11	Siliconized Fiber	150 g/m²
12	%100 Polyester	200 g/m²
13	%50 Wool + %50 Polyester	200 g/m²
14	%20 Bamboo + %80 Polyester	300 g/m²
15	Siliconized Fiber	300 g/m²
16	Siliconized Fiber	250 g/m²
17	Recycled Polyester	200 g/m²

18	Siliconized Fiber	200 g/m²
19	Siliconized Fiber	380 g/m²
20	Goose Feather	350 g/m²
21	Goose Feather	150 g/m²
22	%100 Polyester	130 g/m²

The amount of space and air permeability of the fibers used vary. In addition, some duvets have a special interlining liner produced with micro capsule technology that creates an air-conditioning effect. Some duvets are designed with with 4 seasonal fabrics. In this study, the effects of both fabric and filler on thermal conductivity and thermal resistance will be figured out.

Figure 1: Sample duvets (Manufacturer: Yataş Group – Turkey)

When measuring the thermal conductivity of a duvet, it is, the number of Watts transmitted per meter thickness, physical property that determines the material's ability to transfer heat by direct contact. As a general rule, the lower the thermal conductivity, the better, because the material conducts less heat energy. The thermal conductivity of a material depends on several factors:

- Temperature gradient
- Material properties
- Length of path taken by heat

[1]

$$Thermal\ Conductivity: \lambda = \frac{W}{m \times K}$$

Comparing the relative performance of different material thicknesses means calculating their thermal resistance, that is, the thermal resistance is calculated by dividing the material's thickness by its thermal conductivity.

[2]

$$Thermal\ Resistance: R = \frac{m}{\lambda} = \frac{m^2 \times K}{W}$$

Two-plate method, constant pressure procedure (BS 4745:2005, ISO 5085-1) was used to determine the thermal resistance of textile products. During these measurements, a value called TOG value is obtained as a result of the test. TOG (Thermal Overall Grade) value is a heat preservation and insulation unit that can be used primarily for duvets and bedspreads, but also for all products required for sleep. It refers to the ability of the cover/clothing to trap the hot air around it and thus the amount of insulating containment.

The material to be measured TOG is placed between a metal surface and open air. Duvets are sized as 30 X 30 cm. It is envisaged to use metal with dimensions of at least 100 X 60 cm in the tests for duvets. On the other side of the material, a mechanism is used to keep the air constant at 33°C (which is considered body temperature in the tests). The TOG value in duvets is a method that shows which product is suitable for use according to the seasons.

Different values are used in duvets that change according to the seasons. Products with a TOG value of 3 to 7.5 (avg. 4.5) are preferred for thin duvets used in summer, 9 to 10.5 for products suitable for spring use, and between 12-15 (average 13.5) when the weather conditions are difficult in winter. But here, too, three different duvets are required per year. For this reason, most consumers prefer products with a value of 9+4.5 (13.5 when combined in winter), one thin and one medium density, which can be combined and separated, which can be used in all seasons. The TOG values that should be in the duvets according to different temperature degrees are given in the Figure 2.

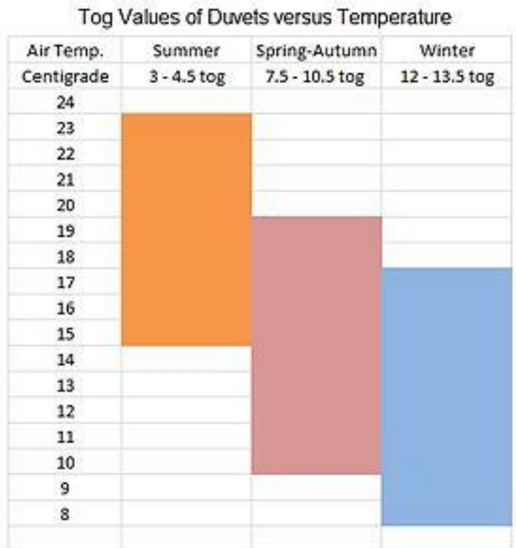

Figure 2: TOG values of Duvets versus Temperature [7]

3. Results

The result of measuring the TOG values of 22 different duvets is given in Table 2.

Table 2: TOG values of duvets

Sample	Thickness (mm)	Thermal Resistance (m^2K/W)	Thermal Conductivity (W/mK)	TOG Value
1	28.7	0.5284	0.0530	5.2838
2	34.8	0.7438	0.0457	7.4377
3	42.5	0.8312	0.0505	8.3132
4	21.8	0,6137	0.0342	6.1369
5	42.5	0,7478	0.0562	7.4775
6	63.5	0.8998	0.0711	8.9979
7	50.1	0.8126	0.0615	8.1265
8	54.9	0.6947	0.0792	6.9467
9	38.7	0.6059	0.0644	6.0591
10	43.7	0.6571	0.0670	6.5705
11	47.6	0.5220	0.0919	5.2203

12	37.30	0.6241	0.0598	6.2414
13	48,20	0.6464	0.0746	6.4637
14	40.00	0.7334	0.0545	7.3338
15	41.47	0.8020	0.0517	8.0201
16	51.85	0.7802	0.0665	7.8023
17	37.00	0.6464	0.0572	6.4642
18	50.20	0.7201	0.0697	7.2012
19	110.00	0.8708	0.1263	8.7083
20	55.00	0.7072	0.0778	7.0720
21	31.00	0.4585	0.0676	4.5851
22	41.00	0.7031	0.0583	7.0313

When the values given in Table 2 are examined, it has been observed that not only the weight or thickness of the duvet, but also the type of fabric and weaving density, the type and amount of filling have an effect on the TOG value. Although sample 9 and sample 11 have the same filling material and filling weight, the TOG values of the two are different from each other. The reason for this is that interlining, which creates a cooling effect, is used in a sample.

Samples 15 and 16 were produced from the same filling material and the same fabric. Only one has 300 g/m^2 of filling, while the other has 250 g/m^2 of filling. A TOG value of 8.0201 was reached in 300 g/m^2 sample and 7.8023 TOG value was reached in 250 g/m^2 sample. In other words, positive effects are observed on the TOG value by increasing the amount of filling.

The effects of different fillings on TOG values were also examined. Samples 10 and 12 have different filling types, but the filling amounts and fabric types are similar. The sample produced from siliconized fiber has a filling amount of 200 g/m^2. The thermal conductivity is 0.0670; the thermal resistance is 0.6571. The sample made of 100% polyester has a filling amount of 200 g/m^2. Thermal conductivity is 0.0598; thermal resistance is 0.6241. Under these values, the siliconized fiber showed higher thermal resistance compared to the polyester sample, and the TOG value was higher.

https://doi.org/10.56038/ejrnd.v2i4.146

The distribution of TOG values is given in Figure 3. TOG values were collected in the range of 7-9. This shows that the products are suitable for use in 4 seasons rather than separating as summer or winter use.

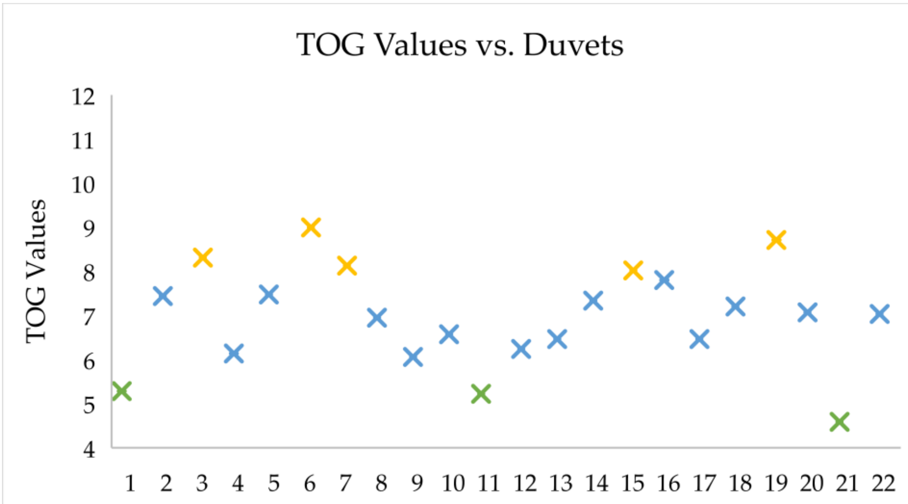

Figure 3: TOG value distribution of duvets

4. Discussion and Conclusion

As a conclusion, the global climate and the changing climate structure are on the agenda of the whole world. Changing living conditions, especially the climate effect, cause an increase in the interest in products that provide more than one use feature. Considering these effects, 4-season products replace summer-winter or seasonal use in the field of home textiles. In order for the product to provide the desired comfort in 4 seasons, it must meet certain standards. With the TOG value, it was measured how much air and heat the duvets passed. As a result of the measurements, it was determined how the content, thickness and filling material of the duvets affect the TOG values. According to the high or low TOG value; the layer thickness and material effect of the duvets and their heat trapping properties were determined. In the new products to be designed, scientific data will replace the designs brought by experience.

5. Acknowledge

We would like to thank to Yataş Yatak ve Yorgan San. Tic. A.Ş. to provide encouragement and patience throughout the duration of this project. Special thanks go to Mr. Erkan EKİNCİ for his valuable and constructive suggestions during the planning and development of this research study.

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