(REFEREED RESEARCH)

OPTIMIZATION OF THE THERMAL COMFORT PROPERTIES OF BED LINEN USING DIFFERENT SOFTENING FORMULATIONS

FARKLI YUMUŞATMA FORMÜLASYONLARI KULLANARAK ÇARŞAF ISIL KONFOR ÖZELLİKLERİNİN OPTİMİZASYONU

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ABSTRACT

This work aims to assess the optimization of the thermal comfort properties of bed linen using different commercial softeners often used in home textiles finishing. Objectively, we intend to study the effect of different softeners and their concentrations, based on non-ionic polyethylene dispersions and a cationic silicone softener micro-emulsion on textile properties. Thermal comfort is related to the sensations of heat or cold, moisture or dryness and influence the performance of textile products used near the skin, such as bed linens. Thus, studies concerning thermal measurements of linen finished samples were carried out using the Alambeta test apparatus. Finally, selected softened samples of bed linen were evaluated by a dry thermal manikin to validate the conclusions. The research showed that thermal related properties are influenced by polyethylene softener. Studies concerning thermal measurements of home textiles with the use of the thermal manikins are quite inexistent.

Key Words: Bed linen, Softener, Thermal properties, Thermal manikin, Alambeta.

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1. INTRODUCTION

The major requirement of a fabric sheet is to be comfortable, nice touch and durable to wear and easy care. Therefore, the finishing of bed linen necessarily implies a softening step.

Softening is a required process stage in the finishing of textile products. It is typically the final step of the finishing process and outcome from the application of compounds, which internally lubricate the fibers and make the tissue more smooth, soft and flexible (1).

This process is done using softeners as auxiliary products with different features (2). The market offers a wide variety of commercial formulations for this purpose, but the composition and price varies considerably.

Moreover, the chemical nature of softeners can either be cationic, anionic or non-ionic, frequently supplied in liquid dispersions. Its application has the purpose to facilitate the process and to improve the fabrics (1).

1.1 Thermal comfort

The thermal comfort is defined as the condition of mind, which expresses satisfaction with the thermal environment. It is a pleasant state of a human being that is psychologically, physiologically and physically in harmony with the surrounding environment (3).

Thermal interaction between man and environment is highly complex, because the person's perception of thermal comfort is affected by several parameters, such as air temperature, air movement (speed), humidity, clothing, activity level, mean radiant temperature (the average temperature of the walls, floor, windows) and many other factors. So, thermal comfort stands for the proper relationship between body heat production and loss. For that reason, thermal manikins can serve research and development in this field, because they are widely used for analyzing the thermal interface of the human body and its environment (4).

Therefore, thermal comfort is related to the sensations of heat or cold, moisture or dryness and influence the performance of textile products used near the skin, such as bed linens.

Most studies on the effect of softeners on textile properties have been focused on the appearance and maintenance properties of materials. Thus, whiteness, pilling formation, wrinkle recovery and dimensional stability were usually considered (2). Also, the mechanical properties were improved by silicone softeners, which are in agreement with that described in the existing literature (5). However, despite the importance of the comfort properties during the purchasing choice by consumers, studies on the influence of softeners on the thermal comfort are rare.

Furthermore, studies concerning thermal measurements of home textiles with the use of the thermal manikins are inexistent.

1.2 Thermal manikins

Thermal manikins have served research and development purposes for more than 60 years. They are widely used for analyzing the thermal interface of the human body and its environment (6).

Thermal manikins provide a good estimate of the total dry heat loss from the body and the distribution of heat flow over the body surface. In a standard environment, these measures can be used to describe the thermal characteristics of clothing (7).

The thermal manikin is an instrument for measuring the thermal insulation of garments and clothing ensemble. It is considered to be one of the most useful tools for evaluating thermal comfort of overall clothing systems. In comparison to other methods for measuring thermal properties of clothing, thermal manikin studies allow to investigate fully assembled clothing in the way these garments are supposed to be used (multi-dimensional), however without any influence of subjective interpretation of human testing or simply physical testing of the materials (bi-dimensional).

2. EXPERIMENTAL

The influence of six different commercial fabric softeners based on non-ionic polyethylene dispersions (designated as A, B, C, D and E), a cationic silicone softener micro-emulsion (H) the mixture between non-ionic polyethylene and a cationic silicone softener (F) and a control sample (unfinished sample G) were studied to determine the thermal comfort behaviour of summer bed linen.

The softeners were added in 5 different concentrations (5, 10, 20, 40 e 150 gL^{-1}) to the finishing bath composed by a resin, a catalyst and a surfactant auxiliary product. After impregnation using a pickup of 60%, the fabrics were dry at 120 ºC during 1.5 minutes and fixed at 180ºC during 30 seconds. A sample without any softener (control sample) was also studied.

Thus, satin 100% cotton fabrics, preferable used for summer linen, weighing 145 g/m^2, before finishing were finished with different compositions of fabric softeners and tested for the thermal properties.

2.1 Test equipment - Alambeta

The tested thermal properties are present in Table 1 and were realized with the Alambeta test apparatus.

This equipment tests the objective evaluation of warm-cool feeling properties of fabric).

To simulate the real conditions of warm-cool feeling evaluation, the instrument measuring head is heated to 32ºC, which correspond to the average human skin temperature, while the fabric is kept at the room temperature 22ºC. Similarly, the time constant of the heat flow sensor, which measures directly the heat flow between the automatically moved measuring head and the fabrics, exhibit similar value (0,07 sec), as the human skin. Consequently, the full signal response is achieved within 0.2 sec (8).

Table 1. Description of the tested thermal properties

Thermal properties	Units
Maximum Heat flux (q_{max})	W/m^2K
Thermal absorptivity (b)	$W.s^{1/2}/m^2.K$
Thermal conductivity (λ)	W/mK

2.1.1 Maximum heat flux (q_{max})

Warm-cool feeling means the feeling we get when the human skin touches shortly any object, in our case textile or other fabric used in clothing, furniture or carpets. It was found, that this parameter characterises well the transient thermal feeling, which we get in the moment, when we put on the undergarment, shirts, bed linen or other textile products. Since this feeling strongly affects the choice of people when buying the clothes or home textiles, the objective assessment of this feeling became very important (8).

The typical time dependence of this heat flow is shown in Fig. 1.

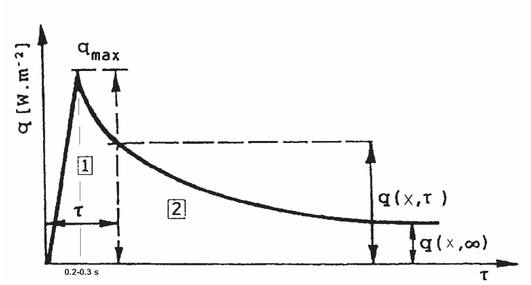

Figure 1. Typical time dependence of heat flow after contact

2.1.2 Thermal absorptivity (b)

The level of thermal absorptivity depends neither on the temperature gradient between the fabric and skin, nor on the measurement time.

Thermal absorptivity can be expressed as:

$$b = \sqrt{\lambda \rho \varsigma}\ , (Ws^{1/2}/m^2K) \quad (1)$$

where:

λ - thermal conductivity

ρ - fabric density

ς - specific heat of the fabric

This value just depends on the structure and composition of the material, particularly the surface properties. The lower the thermal absorptivity, the warmer the feeling during the short thermal contact of the skin with the fabric (8).

Since the thermal absorptivity is mainly the superficial property, its level can be changed by any superficial or finishing treatment, like raising, coating and softening.

2.1.3 Thermal conductivity (λ)

Thermal conductivity is a property of materials that expresses the heat flux that will flow through the material if a certain temperature gradient exists over the material (8).

The measurement result of thermal conductivity is based on the following equation:

$$\lambda = \frac{P.x}{A.\Delta T}, \text{ (W/mK)} \quad (2)$$

where:

P - heat power (W)

x - fabric thickness

A- area (m^2)

ΔT- temperature gradient

The obtained results were treated statistically and the reproducibility of the different results, for each variable, was tested and analyzed.

Finally, selected softened samples of bed linen were evaluated by a dry thermal manikin to validate the conclusions.

2.2 Thermal manikin

The thermal manikin used in this research study is installed in the research laboratory of the Textile Engineering Department of the University of Minho in Portugal.

This thermal manikin use the same basic concept in that the heating power required keeping the manikin surface at a constant temperature is measured and used to correlate with thermal comfort.

The thermal manikin, called "Maria", has a woman's body; its size and configurations are similar to an adult woman.

The manikin is divided in 20 thermally independent sections and only sense dry heat transfer. "Maria" achieves a body temperature distribution similar to a real person. The mean skin temperature of "Maria" can be adjusted.

All tests were conducted controlling the defined air temperature and air humidity. There was a dry heat flow from the manikin's skin surface area through the bed linen into the ambient air, which was measured after steady-state conditions have been reached. We measured the necessary heat flux for the bed linen maintaining the temperature constant at 33 ºC.

3. RESULTS AND DISCUSSION

In order to assess the tested thermal properties, heat flux (Fig. 2), thermal absorptivity (Fig. 3) and thermal conductivity (Fig. 4) were evaluated with the different finished samples.

Comparing the values of heat flux, all softeners increase this property in relation to the unfinished material. We can state that the highest maximum heat flux was reached with the formulation C (non-ionic polyethylene dispersion) with a concentration of 40gL^{-1}.

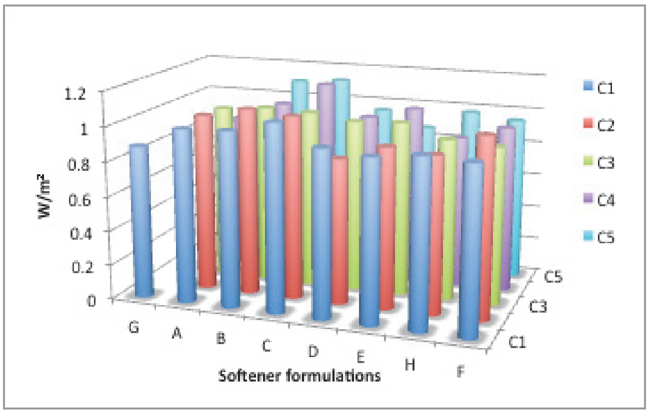

Figure 2. Heat flux (C1: 5 gL^{-1}, C2:10 gL^{-1}, C3:20 gL^{-1}, C4:40 gL^{-1} e C5:150 gL^{-1})

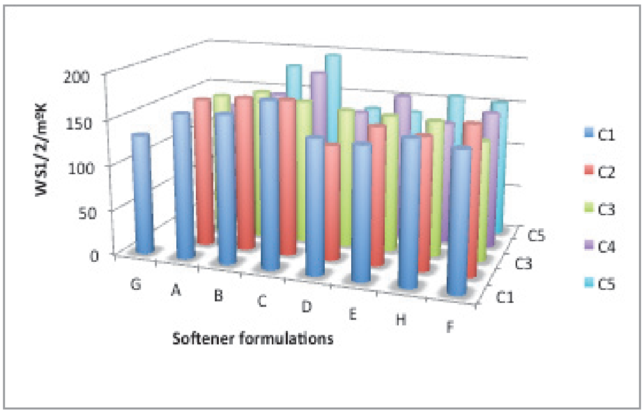

Figure 3. Thermal absorptivity (C1: 5 gL^{-1}, C2:10 gL^{-1}, C3:20 gL^{-1}, C4:40 gL^{-1} e C5:150 gL^{-1})

Comparing the values of thermal absorptivity, all softeners increase this property in relation to the unfinished material. We can state that the highest maximum heat flux was reached with the formulation C (non-ionic polyethylene dispersion). The cationic silicone softener has no significant influence over this property.

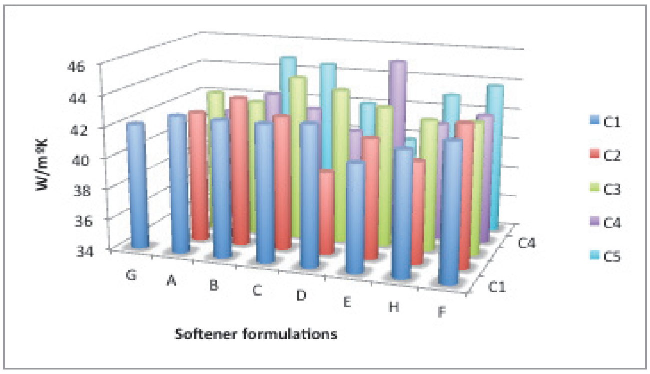

Figure 4. Thermal conductivity (C1: 5 gL^{-1}, C2:10 gL^{-1}, C3:20 gL^{-1}, C4:40 gL^{-1} e C5:150 gL^{-1})

The thermal conductivity were increased with the nonionic polyethylene dispersions formulations B, C and E, for concentrations higher than 40gL^{-1}.

Resuming, it was noted that the application of certain polyethylene softeners improves the thermal behavior, namely the heat flux and thermal conductivity.

The best results regarding thermal behavior was obtained with the application of 40gL^{-1} of softener C and 150gL^{-1} of softener E, , both polyethylene based fabric softeners.

Therefore, thermal heat flux of these formulations was evaluated through thermal manikin measurements (Fig. 5).

The Fig. 6 shown the heat flow comparing the formulation C and E with the measurement of the nude manikin.

We can observe that the finished bed linen isolates substantially the body, regardless of the formulation applied.

Nevertheless, no significant differences were observed with the use of the two different polyethylene formulations of softeners, in terms of thermal comfort (Fig. 7).

Figure 6. Thermal manikin measurements with the selected finished bed linens C and E

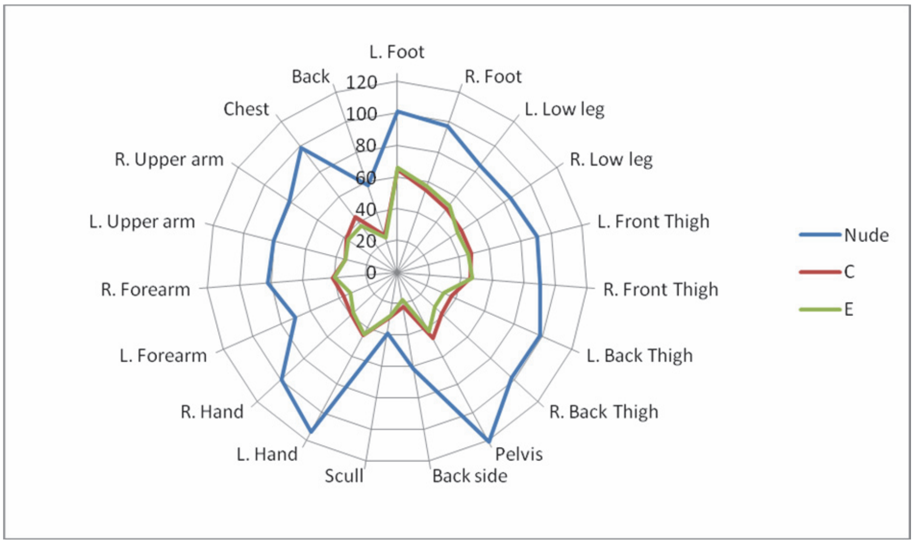

Figure 6. The heat flux (W/m^2) to maintain the skin temperature constant at 33 ºC

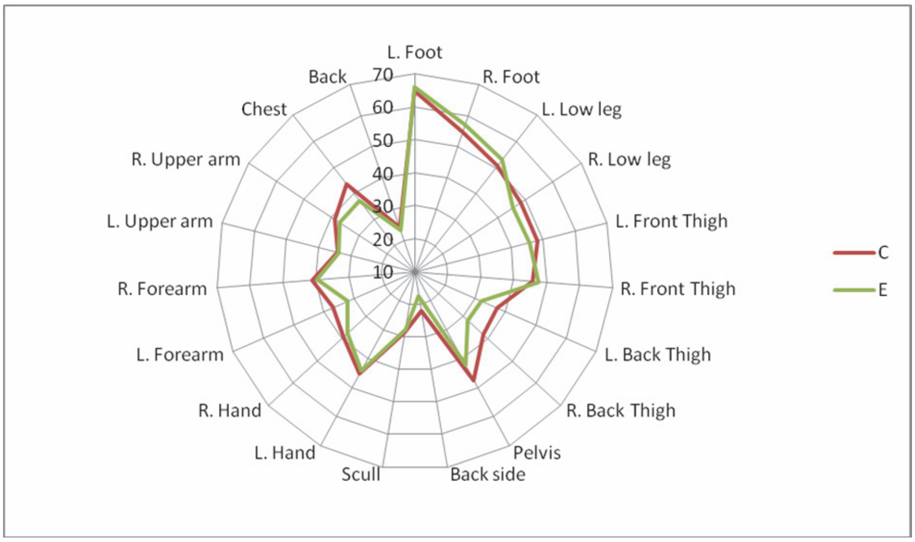

Figure 7. Enlargement of the heat flux (W/m^2) to maintain the skin temperature constant at 33 ºC.

The slight decrease of heat flux (more isolation) observed in the measurements with the softener E (150gL^{-1}), can be justified by the deposition of softener residues on tissue surface, which may create a barrier to airflow and wicking of the fabric, as was explained by Parthiban and Ramesh (9).

Moreover, the bed linen treated with the softener C (40gL^{-1}) need a larger amount of heat flux to maintain the skin temperature constant, hence can be classified as being cooler. These results support the results drawn from the analysis of the thermal conductivity and thermal resistance.

4. CONCLUSIONS

In conclusion, the obtained results showed that commercial formulations of polyethylene differed substantially in terms of the effect caused in the material.

In fact, they influenced the comfort related properties of the material; highlighting the best results using a concentration of $40gL^{-1}$ of polyethylene formulation C from all 40 studied concentrations.

Comfort related properties of the material are changed by polyethylene softener application depending on formulation and concentration.

On the other hand, the silicone softener influence the properties related to the mechanical properties of the material.

Final studies were carried out on dry thermal manikin, showing that no significant differences were observed on bed linen with the use of different polyethylene formulations of softeners, in terms of thermal comfort.

The conclusions of this work still need validation in terms of subjective tactile perception by consumers and will be the next step of this research project.

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REFERENCES

1. Wahle, B.; Falkowski, J., 2002, “Softeners in textile processing. Part I: An overview”, *Review of Progress in Coloration and Related Topics*, Vol. 32, No. 1, pp. 118-124.
2. Chen-Yu, J.; Guo, J.; Kemp-Gatterson, B., 2009, “Effects of Household Fabric Softeners on Thermal Comfort of Cotton and Polyester Fabrics After Repeated Launderings”, *Family and Consumer Sciences Research Journal,* Vol. 37, No. 4, pp. 535-549.
3. ISO 7730, 1995, “Moderate Thermal Environments - Determination of the PMV and PPD Indices and Specification of the Conditions for Thermal Comfort”. ISO
4. Abreu, M. J.; Catarino, A.; Cardoso, C.; Martin, E. , 2011, “Effects of Sportswear Design on Thermal Comfort, in *150 Years of Innovation and Research in Textile Science* of the 11th World Textile Conference, Mulhouse, France, Autex 2011, pp. 50-55.
5. Chattopadhyay, D., Vyas, D., 2010, “Effect of silicon nano-emulsion softener on physical properties of cotton fabric”, *Indian Journal of Fibre & Textile Research*, Vol. 35, No.1, pp. 68-71.
6. Holmér, I., 2004, “Thermal manikin history and applications”, *European Journal of Applied Physiology*, Vol. 92, No. 6, pp. 614-618.
7. Wyon, D.P., 1989 “Use of thermal manikins in environmental ergonomics”, *Scandinavian Journal of Work, Environment & Health*, Vol. 15, No. 1, pp.84-94.
8. Hes, L., Lima, M., 1996, “Effect of Mutual Bonding of Textile Layers on Thermal Insulation and Thermal Contact Properties of Fabric Assemblies”, *Textile Research Journal*, Vol. 66, pp. 245-250.
9. Parthiban, M., Ramesh, K., 2007 “Effect of fabric softener on thermal comfort of cotton and polyester fabrics”, *Indian Journal of Fibre & Textile Research*, Vol. 32, No. 4, pp. 446-452