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THERMAL EVALUATION OF SEATS AND BACKREST WITH NATURAL FIBERS

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Abstract. *This paper presents a thermal evaluation of the seats and backrest of the Luffa Cylindrica. In this study it was compared the thermal effects in the use of the natural fibers (Luffa Cylindrica) and polyurethane foam. Two chairs were covered in the backrest and seat, one with natural fiber and another with polyurethane foam. The body region subject selected for an assessed was a lumbar region and a posterior thigh, regions that are in contact with the seats. Seven thermographic images performed with a time interval of 10 minutes between them, first images collected from the backrest containing Luffa Cylindrica and later images of the back that contained a polyurethane foam collected. After the test, it was possible to identify a temperature difference between the two materials. Considering the results obtained by the authors, the application of the Luffa Cylindrica to seat and backrests is of great relevance since they are a sign of greater thermal comfort for the individuals.*

Keywords: *Luffa Cylindrica, Thermal Evaluation, Natural Fibers, Seats, Backrest*

1. INTRODUCTION

The Luffa Cylindrica, a subtropical plant found in abundance in Brazil, and it known as popularly "bush", and its use is very widespread for cleaning and personal hygiene. This natural fiber presents the characteristic of a rough sponge, abrasive, good resistance of the fibers and of some durability. These characteristics make us believe that by its wide popular use, this fiber ended up gaining an underestimated value for industrial applications. Although there are scientific studies that point out their possibilities of industrial application to generate products with greater benefit.

Some authors identify the enlargement to use Luffa Cylindrica in industrial applications, Chen et al. (2014) explore traction and tension of rupture of the fiber and the structure too, Shen et al. (2012) identify mechanical properties related a rigidity of the material. However, it is known that for the development of specific products, such as seats and backrests, certain properties and characteristics must be identified that meet specific design requirements, such as: thermal comfort, durability, strength, fiber processing, technical feasibility of using large-scale fiber, etc.

Whereas in a popular way the Cylindrica luffa in a certain way meets with its characteristics the functions of sponge, which are produced industrially by the polyurethane foam. And since polyurethane foam is the base material for seats and seat backrests. Thus, considering this analogy of functions, one of the principles of Biomimetics. (Benyus, 2003).

Considering that some parameters need to be identified, thermal comfort is an important feature for seats to ensure the acceptability of the material in industrial use. Thus, the objective of this study is to analyze and compare the temperature provided by the seats made with Luffa Cylindrica fibers and foam with the users.

2. LITERATURE REVIEW

2.1 Luffa Cylindrica

Luffa Cylindrica is a subtropical plant, it is found in several areas of China, Japan, America Central and South America and abundantly in Brazil (Almeida et al., 2005). Satyanarayana, et al. (2009) describe that 62% of cellulose and 11, 2% of lignin compose Luffa Cylindrical, the fruit belongs to the family of the cucurbitaceous (Demir et al., 2006) and the fiber is hygroscopic (Oliveira, 2013).

The plant has a kind of vascular system when is dry form a natural three-dimensional blanket (Almeida et al., 2005), organized in multidirectional way (Satyanarayana, 2007) and entangled around of a nucleus, such a beehive. Is an herbaceous plant and creeper, presents fruits spongy, fibrous, whose can present size among 40 centimeters to 1,6 meter in length. The structure of Luffa Cylindrica's fiber is on figure 1.

Figure 1 - Luffa Cylindrica. Font : Authors.

The most studies found in literature appoint that the Luffa Cylindrica’s fibers used in composites, however Chen, et al. (2014) identified the relationship between the structure of the fiber and their mechanical properties, and identified possible applications of the fiber as covering material.

2.2 Comfort

To Zemp, et al. (2015) comfort / discomfort is subjective and difficult sensation to quantified, however for the authors three subjects are relevant: the comfort was built by factors of personal matter, and it can be affected by several factors (physical, physiologic, psychological) and it is a reaction to the atmosphere to which the human being is exposed.

To Iida (2005) comfort is a subjective sensation produced when no one pressure is located on the body. Is easier speak in discomfort absence, because this can be evaluated. Constantin, et al. (2014) reaffirm that comfort is a discomfort lack, but in many situations comfort can provide the presence of elements that bring satisfaction, relax and pleasure. According to the authors, were identified comfort parameters like temperature, humidity, circulation of air, that provide different comfort notions: thermal comfort, visual comfort, comfort acoustic, comfort hygroscopic, comfort tactile, comfort vibration, etc.

So, the evaluation of comfort/discomfort perception, although based in parameters above mentioned is not the sum of these, but also it demands an interaction of sensations with individual expectations, and psychological factors. All these factors are integrated, and play an important role in the comfort perception. Considering the idea, that comfort has a multidimensional nature, Van Der Linden (2007) indicates that the need should be assisted in all dimensions, as shown in figure 2.

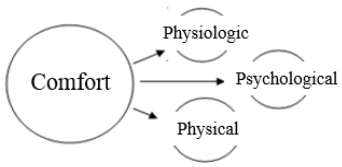

Figure 2 – Adaptation of Van Der Linden Comfort Model. Font: Authors.

In the model proposed by the author, the aspect of physiological comfort linked to the functioning of the human body. The psychological aspects are related to mental comfort and the physical aspects correspond to the interaction between the environments.

According to Silva (2013) the physical aspect of the comfort, known as sensorial aspect, are related with the sensations provoked by–user's skin. For Broega and Silva (2010), a good "touch" provided by the properties of the material used in the finish and the quality of the manufacturing process. Whereas the evaluation of comfort is a subjective process and individual, the authors consider that the important factors related to the physiologic comfort are transfer of heat (transport, convection, radiation and condensation), thermal isolation the dry, absorption of moisture and water vapor through clothing and air penetration. The textile thermal properties, thermal resistance, thermal conductivity and thermal absorption, are influenced by the properties of the fabrics, the structure, composition, density, humidity, as well as the properties of the fibers, the surface treatments, temperature and other factors (Bajzik, 2012).

Broega and Silva (2010), consider that comfort is a fundamental need, once several processes and projects created to make better this aspect in people's life. Textile products especially those that are in direct contact with the user's skin, and are used more frequently, due the sensorial properties about the textile.

Studies accomplished in automobiles identify that the element that causes most discomfort among users is the seat (Constantin, 2014). Comfort is a significant criterion in the project of vehicles for drivers and passengers (Medeiros, 2004).

According to Liu et al. (2011) demonstrated that the temperature of the body-seat interface plays an important role in the user's perception, and that factors as thermal stress can interfere in the psychological and physiologic human performance. Souza comments that (2010) it is necessary to consider several variables as the choice of the foam and of the material of finish used in the seats.

Iida (2005) takes the view that the first comfort condition is the thermal balance, the amount of heat that the organism incorporate should be same that given to the atmosphere. Croitoru, et al. (2015) says that comfort thermal is consequence of all the factors that influence the change of heat between the human body and the atmosphere, and this is subjective. A lot of sensations are influenced by the user´s condition, as age, sex, weight, rates metabolic, factors like clothes, structures of the used material, temperature, resistance, and factors related to the environment as temperature of the air, speed, humidity, pressure and frequency, for that are difficult to consider.

Cengiz and Babalik (2009) proposes that the most important way to determine comfort in seats is the covering material. Souza (2010) affirms the importance of capacity to transmit and change heat between passenger and armchair, this one must be constituted with material that avoids humidity and high temperatures. Each material can have a distinct heat dissipation behavior during the seating position (Pereira, 2013).

Gonçalves (2010) and Pereira (2013) emphasize that the thermal comfort happens when the physiologic efforts of the similar body is minimized to regulating the corporal temperature. Variation of corporal temperature and perspiration are examples of the physiologic efforts produced by the body that are related with the users' dissatisfaction. (Fanger, 1972).

The temperature of the humans body is approximately 37°C, the humans thermoregulator system keeps this temperature to conservation the metabolic functions, the temperature of the skin is approximately 34,1° C, out of these conditions the organism works to maintain the ideal corporal temperature (Fanger,1972). To have a real sensation of thermal comfort, the changes of heat between the body and the atmosphere should happen without efforts.

2.3 Transfer of heat and infrared radiation

The transfer of heat is the traffic of energy among materials, caused by the difference’s temperature. According to the thermodynamics, the objective of the transfer of heat is not only to explain as how this energy is transferred, but also to evaluate the hates in this interaction happens in specify conditions. In this context, when two bodies looking for the thermal balance, the body of higher temperature (T_1) gives the thermal energy enough for the body with lower temperature (T_2), and they find the balance in figure 3.

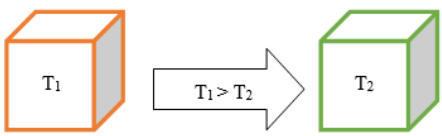

Figure 3 - Change of heat between two bodies. Font: Adaptation of Pereira, 2013.

The basic condition for the change of heat is the existence of difference temperature between the bodies. The transfer of heat transport happens when the particles of the material get in touch with a thermal source, increases the agitation state, transmitted for the closest particles and so forth (Villas Bôas, 2010). The thermal changes happen in four ways: transport, convection, thermal radiation and evaporation. The focus of this study is the head transferred by radiation, a transfer of heat that happens without the material to spread, this phenomenon occurred because surfaces that present different temperatures from the absolute zero emit energy in electromagnetic waves.

The propagation of the energy electromagnetic is called radiation (Villas Bôas, 2010) and it happens in four ways: emission, absorption, reflection and transmission. The emission happens when a material liberates energy, the absorption when the material keeps energy, the reflection happens when it occurs with the same material and the transmission happens when the energy crosses the material.

When the total radiation or part of this is absorbed by the surface, then an increase of the thermal energy of the material occurs. The capacity to absorb and emit the own radiant energy in form of infrared radiation is called "emissivity" (ε). (Incropera and Dewitt, 2008). According with their physical characteristics the waves can be classified as mechanics and electromagnetic. The mechanic waves are originating from the propagation of energy through the particles of a material and don't spread in the vacuum, already the electromagnetic waves were formed by an electric and magnetic field, this kind of waves spread in the vacuum. The electric and magnetic fields are perpendicular amongst themselves. As larger the frequency of the waves electromagnetic, more energy this possesses. The electromagnetic waves in totality transport energy, but only the strips around of infrared, are called waves of heat. The infrared when is absorbed transforms in thermal energy.

All the objects with temperature above the zero absolute (T = 273°C = 0 K), emit proportional infrared radiation, including the human body, special in the spectrum of long infrared (Brioschi, et al., 2007). Anybody with temperature above the absolute zero emits thermal radiation; this occurred because vibration and rotation movements of atoms and molecules. Warmer is an object, bigger is the infrared energy emitted by this. This radiation can be contemplated, absorbed, emitted and transmitted through a solid body.

To measure the infrared radiation emitted by the surface of the body is used infrared thermograph, to Meola, et al. (2006). The thermograph has as purpose to identify areas that present characteristics different from the standard, with a thermal map of body. It is an emerging technique in some areas, but presents positive results (Pereira, 2013). Has wide applicability, is growing in several areas that involve the human activity and the results of this tests are safe, fast and immediate. (Sales, et al., 2007)

Images create by thermograph camera is called thermogram (figure 4). In these images is possible measure the variation of the temperature of the human skin (Alahmer, et al., 2012). According to Pereira (2013) the thermogram shows the difference of temperature in an element, in the form of coloration gradients, with different colors and they are based on the physics of the radiations and thermoregulation of the body (Souza, 2014).

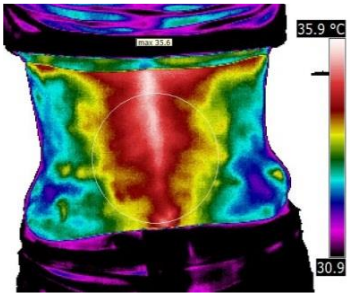

Figure 4 - Thermogram. Font: Authors.

For Alahmer, et al. (2012) with thermograph is possible measure the temperature in a surface of a solid, clothes and visible parts of human body. Rossignoli, et al. (2014) affirm that the infrared thermograph supplies information on physiologic processes registering and interpreting the temperature of the skin.

However great parts of studies found on the literature about thermograph are related of constructions, but studies done by Lima (2006) and Pereira (2013) identify that infrared thermograph is a good alternative for analysis of thermal comfort of seats.

3. MATERIALS AND METHODS

The materials used to realize the experiment was a FLIR Thermograph Camera, two seats covered with automotive fabric, the seat (A) was filled with fibers of Luffa Cylindrica and the seat (B) was filled with foam. To analyse the results was used a Minitab software.

Five subjects was selected to participe of the experiment, 3 males and 2 females, young adults. The clothes use by users was a cotton t-shirt and "jeans" pants, this clothes was chose because acording several authors the material used cannot cause interference in the experiment. The experiment was realized in Ergonomics Laboratory of University State of Paraná, and the ambiance temperature was maintained in 24° Celsius.

To realize the tests one protocol was created by the authors (figure 5), in this document they defined that four pictures with the thermograpf camera will be taken in four diferente times, in each seat.

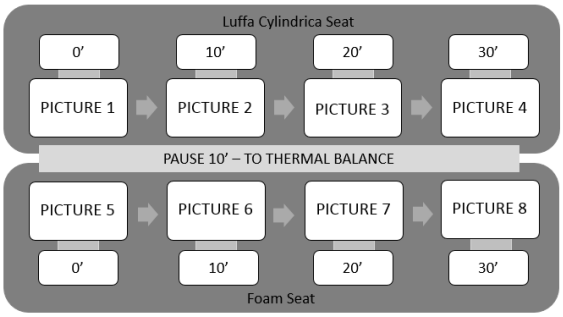

Figure 5 - Protocol to analyse the temperature in seats. Font: Authors.

First the picture was taken in Luffa Cylindrica seat, the picture one (1) was taken before the user stay in contact with the seat, to verify the temperature in the seat after this, the user stay in contact with the seat for 10 minutes and the picture two (2) was taken, the user stay in contact with seat more 10 minutes and the picture three (3) was taken, so the picture four (4) after 10 minutes was taken, was totalized 30 minutes. To start the experiment in other seat, it was necessary 10 minutes to thermal balance of the body, so this time was included in the procedure after this, the authors start the procedure to analyse the seat filled with foam, and the time and order of pictures was respected. To the time between the pictures, 10 minutes was necessary, because some authors affirm that after 10 minutes the person start to feel discomfort in the same position, so have a tendency to move the body and consequently move the point that was in contact with the surface and the temperature could change in that point.

In the thermograms six points of contact was chose to analyse the temperature proportionate by the seats, four points in backrest and two points in seat.

4. RESULTS AND DISCUSSION

The temperature obtained in Luffa Cylindrica seat is on table 1, and the temperature obtained in Foam seat is on table 2.

Table 1 - Temperatures obtained of Luffa Cylindrica seat.

		User 1				User 2				User 3				User 4				User 5			
Temperature (°C)	Point	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	1	34,4	34,3	36,5	35,7	31,4	30,5	30,8	28,4	30,0	29,0	29,0	30,7	32,5	31,4	33,5	32,6	34,3	35,5	34,6	34,0
	2	34,4	34,1	36,5	35,9	31,2	30,2	30,6	28,5	30,2	29,4	28,8	31,0	32,1	31,9	33,4	33,2	34,2	35,7	35,2	34,6
	3	33,0	34,0	35,4	35,0	31,1	31,2	30,8	28,1	28,3	27,1	25,9	28,3	28,5	29,4	32,1	31,0	32,3	34,3	34,3	34,4
	4	32,9	33,3	35,1	34,8	31,2	30,3	30,5	28,3	28,6	27,3	25,8	28,7	28,9	29,6	31,8	31,0	32,7	34,4	34,6	34,2
	5	33,2	34,8	37,7	36,2	32,2	34,0	34,9	33,5	26,6	28,0	27,3	28,7	28,1	30,5	32,8	33,1	32,3	34,4	34,7	35,0
	6	33,4	35,1	38,0	36,6	32,0	33,3	34,1	32,9	27,1	28,3	27,6	30,0	26,8	29,9	32,3	32,2	32,6	34,3	35,0	34,9

Table 2 - Temperatures obtained of Foam seat.

		User 1				User 2				User 3				User 4				User 5			
Temperature (°C)	Point	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	1	34,8	35,2	35,1	34,3	29,0	29,6	31,0	29,1	28,4	29,0	30,5	31,1	33,4	32,7	31,8	32,5	31,7	31,8	34,4	34,5
	2	34,6	35,0	35,1	34,2	28,9	29,6	30,9	29,0	29,1	29,7	30,7	31,1	33,7	33,1	31,5	33,0	32,0	32,1	35,7	35,1
	3	34,4	34,0	33,7	33,4	29,7	29,9	30,4	30,5	26,0	27,0	28,1	27,9	30,4	30,1	29,5	30,2	29,5	31,1	33,1	33,2
	4	34,5	34,0	33,6	33,2	30,2	30,4	31,0	31,1	26,6	27,3	28,5	28,4	30,1	30,4	29,1	29,6	29,4	32,5	33,4	33,3
	5	33,0	36,6	36,6	33,1	33,8	34,6	34,8	33,6	26,1	27,8	29,7	26,9	31,3	31,0	29,8	30,3	28,2	31,7	33,3	33,6
	6	32,7	36,3	36,3	33,1	33,5	34,2	34,5	33,5	27,3	28,0	28,9	27,7	31,4	31,4	29,7	30,2	28,3	32,4	34,0	34,1

Analyze the temperature obtained in the experiment is possible to identify the difference proportionated by two seats, and verify the behavior of temperature in the users.

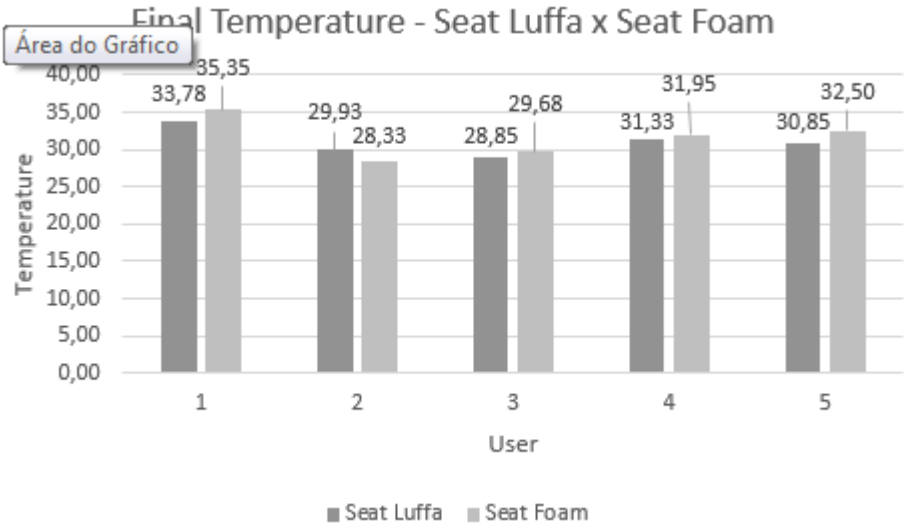

Figure 6 – Analyse of final temperature between the seats. Font: Authors.

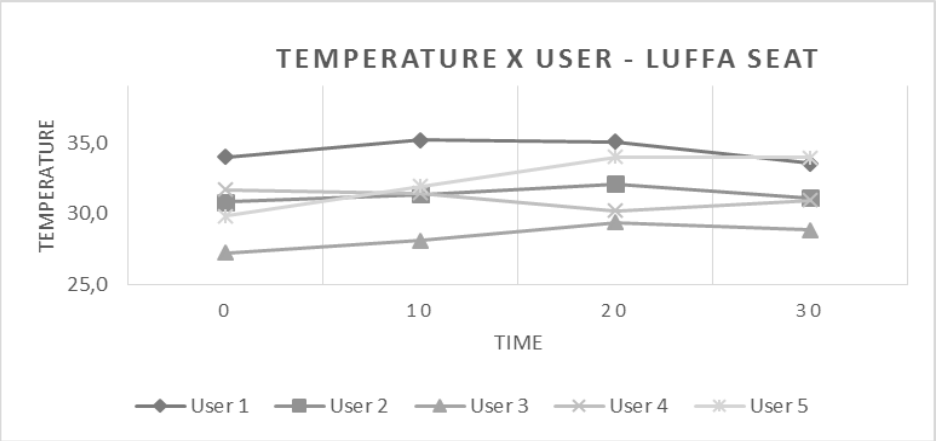

Figure 7 – Evolution of temperature x user in Luffa seat. Font: Authors.

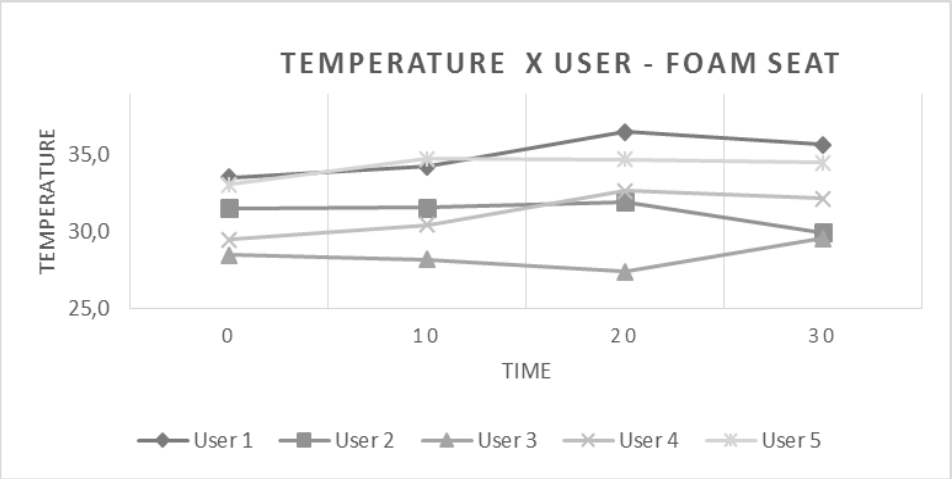

Figure 8 – Evolution of temperature x user in Foam seat. Font: Authors.

On figure six (6) is possible indentify that the temperature emited by the users body, after 30 minutes is higher in foam seats exepted in user two. To identify this behaviour is necessary an study about the influence of corporal mass of each user. Another information extract of this graphic is that the user 1 and 5, have a body temperature one °C higher than others users and coincidentally this users are women. With this analyses, is possible identify that the "biotype" of users interferes directly in the results obtained.

On figure seven (7) and eight (8) is possible to see the temperature taken of users along the time on two seats. The Luffa Cylindrica seat (figure 7) we can see the temperature at this early moment is high, this could be related with the first contact on interface seat/user and this behaviour is inevitable, once ocurred the transference of heat between the bodyes with diferent temperature, and in the second moment the temperature tends to reclive, probably this is relationated with the struture of fiber that allows larger aeration of the seat, allowing larger and better passage of air, what provides better thermal comfort. On foam seat (figure 8) is possible to see that occur there was a rise in temperature in the first moment,but after this phase a certain temperature is reached, which tends to remain stable that can cause discomfort on user. However the user 2 and 3 presents behavior different from the other users, on user 2 the temperature after first contact decreased drastically and on user 3 the temperature decreased and later it increased, presenting a behavior different from other users.

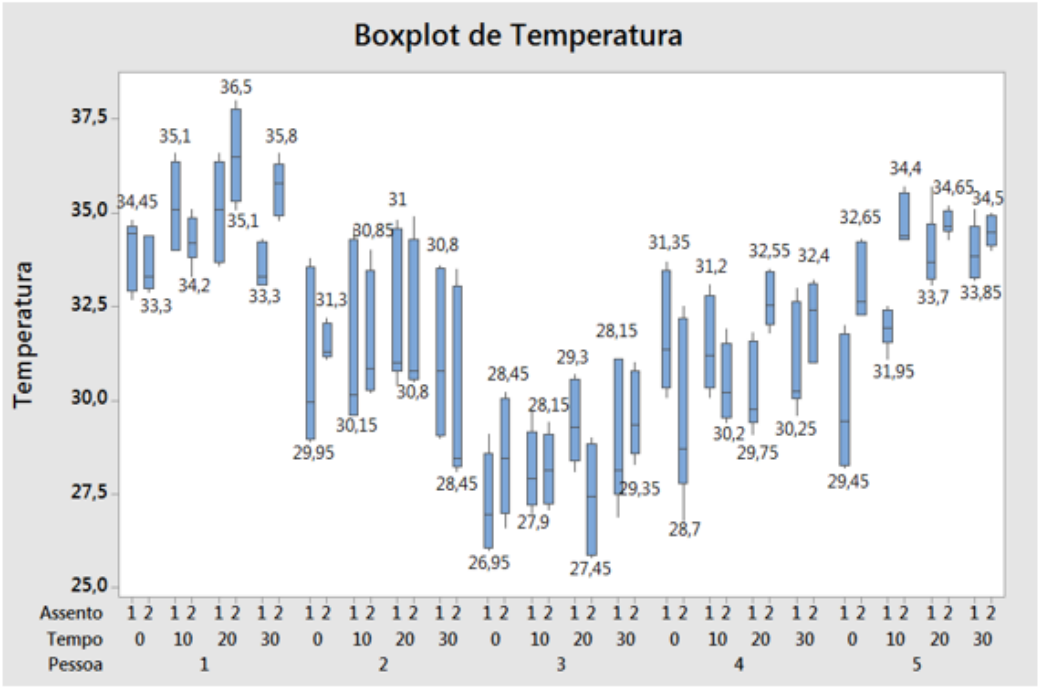

Figura 9 – Boxplot of temperature. Font: Authors.

And on figure nine (9) is possible to see that the variation of temperature on foam seat is bigger than the variation on Luffa Cylindrica seat in large part of the seats, and the inicial temperature on foam seat is always bigger than the temperature on Luffa Cylindrica seat, it is probably relationated with the emissivity of the material. The user 2, in this case also presents a diferent kind of behaviour when compared to the other users. The value on grafic corresponds the medium of the temperatures obtained in the experiment.

5. CONCLUSIONS

In this study, the results present that the Luffa Cylindrica seat is an advantage front the foam seat, in relation of temperature proportionated to the users, but is important standardize the users to realize the experiment. In this study shows too there may be interference in the results, generating many residual data and this could influence the credibility of results obtained.

To future study, should be interesting identify and compare the hate of cooling of this material, once just the heating was study until this moment. Another study of this research, should be identify the emissivity of this materials to know if this point could be considering a variability of the experiment and which is the influence in the obtained results.

The study shows that the thermal comfort proportionated by the Luffa Cylindrica seat is better than the foam seat, but is ideal to design a prototype with the mix of these fibers, to improve the comfort proportionated by the foam seats, repeat the thermograph tests and measure the comfort proportionated by these new concepts. Another point that is considering is that the natural fibers need a chemical treatment anti-fungal to delay the degradation and analyze if it could influence the results.

6. ACKNOWLEDGEMENTS

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