STUDY ON THERMAL DISCOMFORT OF MOTORCYCLE HELMET USER

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STUDY ON THERMAL DISCOMFORT OF MOTORCYCLE HELMET USER

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A thesis submitted
in fulfillment of the requirements for the degree of
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DECLARATION

I declare that this thesis entitled " Study On Thermal Discomfort Of Motorcycle Helmet User " is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality as a partial fulfilment of Bachelor in Mechanical Engineering (with Honours).

Signature : ....

Supervisor Name : Dr. Abd Rahman Bin Dullah

Date : ....

DEDICATION

Highest gratitude to Dr. Abd Rahman bin Dullah from Faculty of Mechanical Engineering for his encouragements and guidance towards me to complete this thesis. Also, to my beloved family members and friends whom helped me in completing this thesis.

ABSTRACT

Thermal comfort is a state of mind that represents fulfillment with the environment. Thermal comfort varies from one person to another. To maintain thermal equilibrium it is necessary that the heat generated as a result of human activities is made to dissipate at a rate to maintain equilibrium within the body. Discomfort occurs when the heat gain or heat is beyond this result. Climate change is becoming undeniably significant every day which is beneficial neither for human population nor the planet. This directly affect thermal comfort level in our surroundings. However, it is difficult to curb it all at once. It is necessary to look into possible aspects that can be explored and studied that may contribute towards the betterment of the environment. It is important to measure microclimate parameters quantitatively within the helmet and link to the human perception. The importance of the parameters influencing the thermal comfort varies with the climate of the countries. In many cases, the air temperature has been considered the major influencing factor to the thermal comfort and many of the indexes produced are mainly focusing to the determination of the comfort temperature. The purpose of this study is to measure multi-point temperature and relative humidity inside a helmet while human subject wearing it on head using micro sensors. Test rig was developed using three types of the motorcycle helmets which is with full face helmet, open face helmet and half face helmet. The exercise bicycle used for the human subject to sit on it and run it in order for them to out the heat and sweat from their head and body. The micro sensors measure the both temperature and relative humidity which is from the heat transfer from the subject's head to the helmets. This depends on subject's body type and head size. There is up to five subjects were tested for each type of helmets. Results give the original measurements of the in-helmet micro climate. Results also show some interested interaction between the in-helmet temperature and relative humidity.

ABSTRAK

Keselesaan terma adalah keadaan minda yang mewakili pemenuhan dengan alam sekitar. Keselesaan terma berbeza dari satu orang ke satu sama lain. Untuk mengekalkan keseimbangan termal, perlunya haba yang dijana akibat aktiviti manusia dibuat untuk menghilangkan kadar untuk mengekalkan keseimbangan dalam tubuh. Ketidakselesaan berlaku apabila mendapatkan haba atau haba melebihi peringkat ini. Perubahan iklim menjadi tidak dapat dinafikan setiap hari yang tidak memberi manfaat kepada penduduk manusia mahupun planet. Ini secara langsung mempengaruhi paras keselesaan terma di persekitaran kita. Bagaimanapun, sukar untuk membendung semua sekaligus. Ini adalah perlu untuk melihat aspek-aspek yang mungkin dapat diterokai dan dikaji yang boleh menyumbang kepada peningkatan alam sekitar. Ini penting untuk mengukur parameter mikroklimat secara kuantitatif dalam helmet dan menghubungkannya dengan persepsi manusia. Kepentingan parameter mempengaruhi keselesaan termal berbeza dengan iklim negara-negara. Dalam banyak kes, suhu udara telah dianggap sebagai faktor utama yang mempengaruhi keselesaan termal dan banyak indeks yang dihasilkan terutamanya memberi tumpuan kepada penentuan suhu keselesaan. Tujuan kajian ini adalah untuk mengukur suhu pelbagai titik dan kelembapan relatif di dalam topi keledar manakala subjek manusia memakainya di kepala menggunakan sensor mikro. Peralatan eksperimen dibentuk dengan menggunakan tiga jenis topi keledar motosikal iaitu topi keledar muka penuh, topi keledar muka terbuka dan topi keledar separuh muka. Basikal senaman yang digunakan untuk mata pelajaran itu untuk duduk di atasnya dan jalankan agar mereka keluar dari panas dan peluh dari kepala dan badan mereka. Sensor mikro mengukur kedua-dua suhu dan kelembapan relatif yang berasal dari pemindahan haba dari kepala subjek ke helm. Ini bergantung pada jenis badan dan saiz kepala subjek. Terdapat sehingga lima subjek manusia yang diuji untuk setiap jenis topi keledar. Hasilnya memberikan pengukuran asal mikroklimat dalam helmet. Keputusan ini juga menunjukkan beberapa hubungan antara suhu helmet dan kelembapan relatif.

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CHAPTER 1

INTRODUCTION

1.1 Background of the project

Lately, the residents of Malaysia really depend on motorcycles for their daily mobility. Traveling on motorcycles has its own flexibility compare to other transportation because it has its own advantages like low-cost maintenance, easy to travel in congested roads, able to ride in narrow and broken roads and the prices are affordable too. The most number of people in Malaysia using motorcycles as the main option of transport on their everyday routine for business, work and school-related travels. Helmets are of important personal protective equipment (PPE) that each person needs to wear when they ride their motorcycles to protect their head against impact during any accidents. The helmet helps to prevent the severity and frequencies of head and brain injuries resulting from motorcycle accidents. A helmet is also largely important in preventing motorcyclists from serious neck and head injuries when a crash occurs. Motorcyclists will be having great challenges when riding their bike on the road whereas involving in the road crashes mostly in the rural areas where the road and the traffic networks are busy and complex. The National Highway Traffic Safety Administration, NHTSA (2007) has been revealed that the injury rate for motorcyclists is about eight times more likely to exist than the injury rate that involves car users. Therefore, wearing a helmet is compulsory for a motorcyclist to prevent their deadly head and neck injuries and enhance the safety measure within the motorcyclists. Indoor comfort for the occupants can be classified into three such as thermal comfort, visual comfort and indoor air quality. Comfort is defined as the sensation of complete physical and mental well-being. Thermal neutrality, where an individual desires neither a warmer nor a colder environment, is a necessary condition for thermal comfort. The factors affecting comfort are divided into personal variables such as activity, clothing and environmental variables will be air temperature, mean radiant temperature, air velocity and air humidity. Besides that, thermal comfort is one the common factor when wearing a helmet.

Thermal comfort describes a condition of mind of a human that satisfies the thermal environment, Toh Yen Pang, A. S,(2011). The strongest thermal comfort sensors of a human body are their heads. This is where the thermal comfort comes into a question. There is a complaint among people about the headgear in warm environments related to thermal comfort. The helmet enhances heat loss and enlarges thermal comfort in a warm environment with the appearance of wind. The helmets can cause problems for the user of the motorcyclist by factors such as CO_2 and O_2 concentrations. The airflow around the head of the helmet user will decrease and it leads to an increase in heat-related stress in leisure, play and recreation activities. Moreover, the helmets can cause thermal discomfort when the user wears it during warmer days or the under hot sunny day when riding on the motorcycle. Heat stress can cause discomfort due to the heat generated within the helmets and it leads to damage the performance of the daily activities such as correct and rapid decision making and focused attention. Heat transfer approach from the head will take as a medium in this study without considering other parts of the human body. This study will focus on the heat transfer and the convective heat loss of a motorcycle helmet user.

1.2 Problem statement

In this era of globalization, one of the world's main concerns is thermal comfort. Nowadays, thermal comfort is being considered by humans for their daily needs and also to run their daily lives. On the other hand, thermal comfort is based on the surrounding environment. Therefore, the surrounding environment must satisfy the perception and condition of the mind of a human in order for them to feel comfortable. This is because every human in the world wants to live a comfy and luxury life and it does depend on the surrounding environment. These do apply to a motorcyclist who is wearing a helmet during his traveling on his bike for his daily activities. Hence, a safer option of a helmet to protect the motorcyclist user should be considered.

The helmet of a motorcyclist must be taking into account benchmarks such as must depends on the head size, the temperature of the body and the types of the helmet in order to have a better thermal comfort. Furthermore, the heat transfer of a human's head to the helmet needs to be tested using the sensors and thermocouples. This will give the results depends on each of the individual body temperatures. This approach also could further satisfy the benchmarks mentioned before which were the head size, body temperature and the types of helmet.

1.3 Objectives

The objective of this project is as follows:

1. To determine and analyze the temperature and relative humidity inside different helmets by human testing.
2. To investigate the effect of different head size and the heat transfer on the thermal comfort of a helmet user.

1.4 Scope of project

The scopes of this project are:

1. The test rig of the helmet setup will be built based on the ventilation holes on the each type of the helmet.
2. The experiments will carry out for testing the parameters such as minutes, level of humidity, human perceptions and the surrounding temperature changes and will be taken down and tabulated based on the subject being tested.
3. There are 3 types of the helmet will be tested using 5 subjects for each of the helmet.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A human being in this world able to focus and be effective in whatever activity they intend to do in a comfortable and pleasant environment. Thermal comfort is defined as a matter of comfort of a person's surrounding environment. Thermal comfort is one of the important aspects which plays a role in human life to bring out an amazing environment. Nonetheless, materials and substances occurring in nature are being exploited in a larger volume in order to achieve a high level of thermal comfort. This will influence and devastate the environment as well as the unhealthy activities that will turn result in bad effects on climate. Hence, it is important to study about thermal discomfort of motorcycle helmet user and perform a better purpose of achieving the desired level of human comfort. This particular chapter will review studies and researches carried out about the thermal discomfort on different types of motorcycle helmet and body temperature of the user.

Based on the research paper (Havenith.K, 2010), humans head can produce up to 50% of the produced latent and sensible heat loss when insulating with any types of item such helmets or any clothes worn on it. Large sweat production on the human head in order to maintain thermal neutrality in warm environments. Different body parts produced to vary the quantity of sweat and distribution changes with changing non-thermal (work rate) and thermal conditions showed spatial differences in sweat production on the human skull. The spatial and temporal gradients in latent heat loss of the human head allow optimization of headgear for thermal comfort if these measures are validated by thermal comfort studies. Furthermore, a head and a headgear could be optimized by using thermal manikins in Figure 2.1 to evaluate heat accumulation in a realistic way. The thermal manikins been used and do not consider the dynamics of (latent) heat loss.

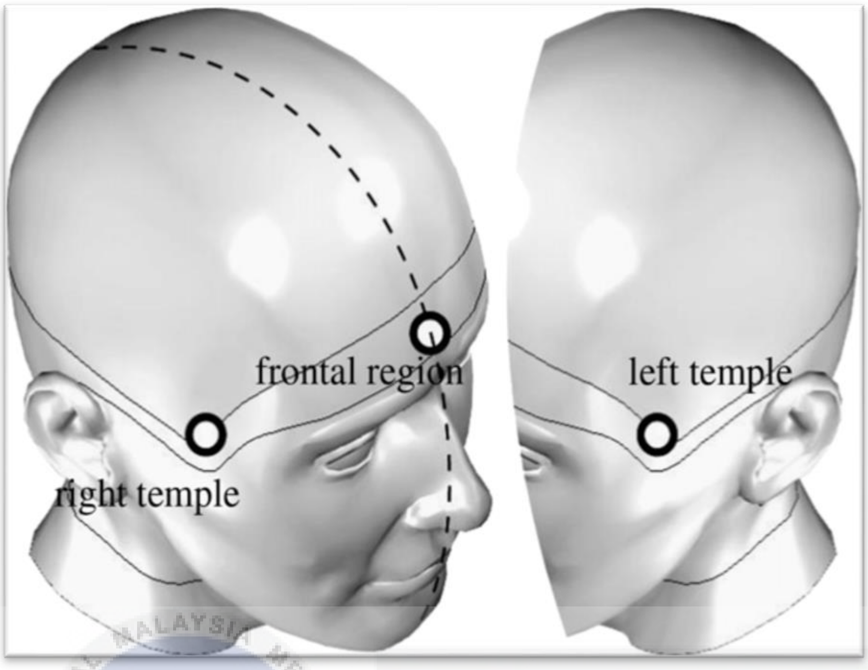


Figure 2.1 View of the three sites of the head where sweat production measured

Source: Havenith.K,(2010)

2.2 Simplified thermoregulation model of the human body

According to (Chelliah, B. K., 2015), the thermal connection of the human body with the environment includes two procedures which are the heat exchange between the human body and the thermal environment, at the same time including radiation, convection, conduction, respiration and evaporation; and the self-control function of the human body which reacts to fluctuated thermal environments, for example, vasoconstriction, vasodilation, sweating and shivering. According to (Parsons.K,2014), thermoregulation models of the human body are grown to reenact these two procedures of interaction and foresee the human thermal reaction under various thermal conditions and have been generally utilized in the field of physiology or thermal comfort studies. Furthermore, precise thermoregulation model will help enhance the exactness of the present thermal comfort forecast models, and give an essential hypothetical examination of the precision of the different models in the application.

There are various types of models used in thermoregulation. One of the most famous used in thermal comfort study is the simplified Gagge's 2-node model, (Gagge.A.J,1971). Moreover, there are many types of complex thermoregulation models which have been grown by enhancing the modelling of body segmentation, especially for heat insulation, thermoregulatory systems and heat exchange,. The mean skin temperature was utilized for the approval of the developed model. In the current research, skin temperature has been exhibited to be emphatically identified with the thermal interaction between the human body and the thermal environment, which is likewise an imperative pointer of thermal comfort. It has been effectively used to approve progressively complex and modern prescient models for thermoregulatory reactions, and to assemble thermal sensation models. Furthermore, based on (Yang, Y. Y.,2015) there are some characteristics which caused by individual differences in human thermal responses which are gender, age, height, weight and there are also consists of some major differences between human which are the skin composition, fat composition and muscle composition as different human body has their different composition. In Figure 2.2 shows the thermoregulation model of a human body that heat flows showing the interrelationship of the physiological and external factors that influence thermoregulation.

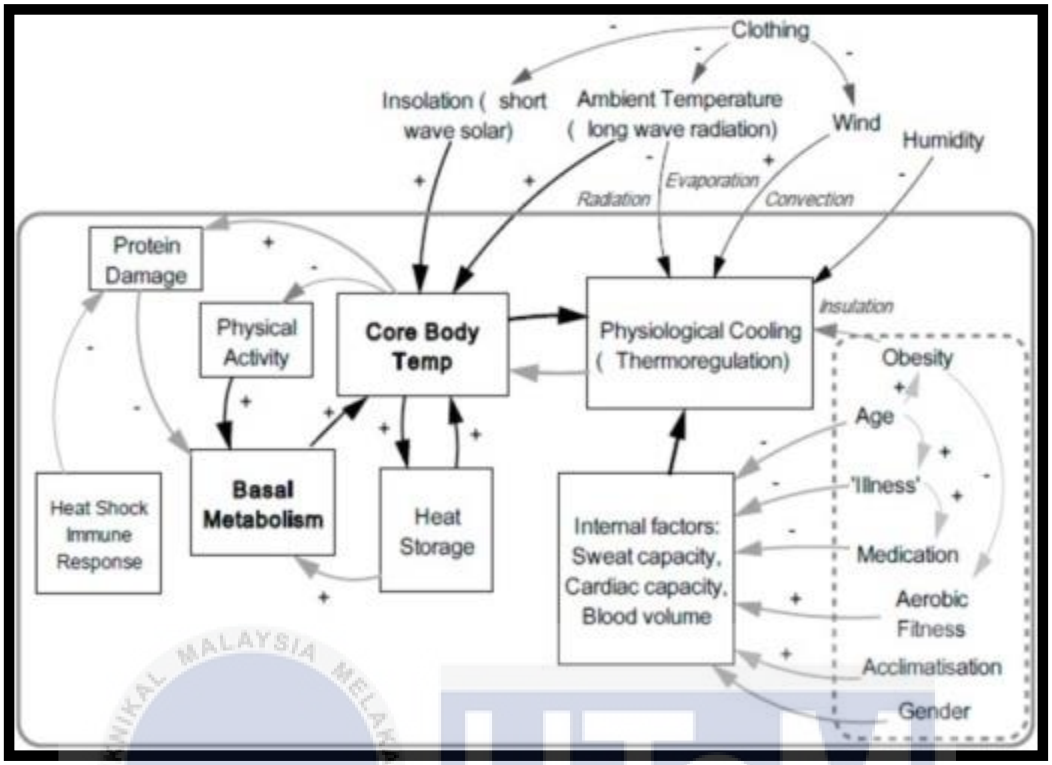


Figure 2.2 Thermoregulation model

Source: Gagge.A.J,(1971)

2.3 Thermal and moisture test on industrial safety helmet

According to (Mills.N.,2008), construction or collecting of a manufacturing line is generally a physically requesting movement with specialists working for times of up to 8 hours in multi-day. By and large, such movement could be much additionally requested by the way that labors are required to wear defensive hardware so as to avert genuine damage that may come about because of being hit by falling nuts or potentially screws. Joined with the way that development or gathering are regularly done in the heat of summer, this may offer ascent to physiological and mental strains for specialists who need to wear helmets to shield their heads from damage by law. It is hence crucial to limit any uneasiness that may result from this equipment, so as to guarantee the ideal conditions are accessible for the users. This uneasiness might be either, thermal discomfort as far as heat and sweat, or mechanical because of friction or aggravation.

Different designs and material choices were had to augment effect opposition of the helmet. A general survey of research on modern protective helmet configuration was given by Proctor in mid-1980s. The review secured insights on the occurrence and seriousness of head injuries in accidents where protective helmets were being worn, as contrasted and those where helmets were not being worn. Be that as it may, according to (Davies.C.,1979), the comfort which managed by the review was for contact mechanical pressures, despite the fact that the review called attention to inconvenience could likewise be caused by a high temperature inside the helmets. Subsequently, thermal comfort was not a noteworthy issue around then for modern protective helmets, in spite of the fact that researches on how skin temperature influence on sweating and oxygen-consuming activities amid extreme work was done.

Thermal comfort has drawn consideration and pulled in some studies since the 1970s. Early research was embraced by utilizing secluded fluid cooled protective helmets liner in space explorer helmets to enhance thermal comfort, (Williams and Shitzer,1974). There are three types of industrial safety helmets have been tested as shown in Figure 2.3.

The Type I is white protective helmets aside from the Type II was furnished with 22 little gaps (3 mm in breadth) in the front, the side and the top regions. The Type II protective helmets were the red helmet that had 6 manufacturing ventilation openings measured 2x5mm each on the top region. Therefore, measurements uncover that the ventilation openings are critical to direct the smaller scale climate inside the helmet, in order to the thermal comfort

Figure 2.3 Type I, type II helmet respectively with and without ventilation openings

Source: Guan.Z,(2014)

2.4 Internal ventilation sweating model for motorcycle helmet

According to (Pinnoji.P,2006), the design of motorcycle helmets customarily centres around the auxiliary exhibitions that they have to fulfil. In reality, its major job comprises in forestalling injuries for the head of the rider by engrossing and appropriating the accidents happening amid accidents. As of late, mechanical makers began to research their liquid powerful properties as well, motivated by execution enhancement in perspective of races (i.e. drag decrease by mean of shape improvement) and in addition comfort-related issues, for example, upgraded inward ventilation frameworks or noise decrease. Moreover, according to (Cimolin.F,2010), a ventilation framework is an arrangement of channels burrowed over the smaller insurance layer of the helmet which must have the capacity to make some crisp outside air intakes inside it, going from a progression of air admissions situated in the front piece of the helmet towards outtakes situated in the back one. At present helmet, producers experience the ill effects of a total absence of liquid powerful rules for the plan of such channels, which are set just by involvement, without adequate proof of giving appropriate ventilation.

The body should discharge heat and sweat from its contact interface, whose removal by conduction and convection is requested to the stream field as shown in Figure 2.4. Evaporation is the central phenomenon that should be displayed, which is dependable of changing sweat into water vapour, equipped for being advected away frame the texture by the wind stream. A genuinely reasonable presumption is to keep the liquid elements decoupled from the thermodynamics, attesting that the nearness of sweat does not influence the attributes of the stream inside the permeable medium and that the lightness impacts in the liquid space can be disregarded. This implies the speed field can be registered in a starter stage and afterwards utilized just for what concerns shift in weather conditions. In addition, for straightforwardness, we will guess the stream field to be characterized at relentless state, along these lines without time reliance.

According to (Thorvaldsson.K,1999), at the point when some sweat is discharged from the body towards the permeable zone, it can evaporate as per a specific rate contingent upon the nearby estimations of both temperature and humidity. The evaporation procedure is nothing else that a stage change, i.e. the water in fluid stage (sweat) is changed over into water vapour, which can be advected away by the stream field. The evaporation procedure requires energy and this causes a temperature diminishes. The coupling of the advancement conditions for the three scalar questions lies precisely in the response (evaporation) term. A thermodynamic model for the investigation of the inner ventilation for motorcycle helmets, fit for portraying both the heat exchange and the sweating related wonders, has been plot. It depends on the coupled development of the three scalar questions temperature, supreme humidity and sweat (characterized just in the permeable space as a thickness joined to the fibres), connected by methods for the evaporation term.

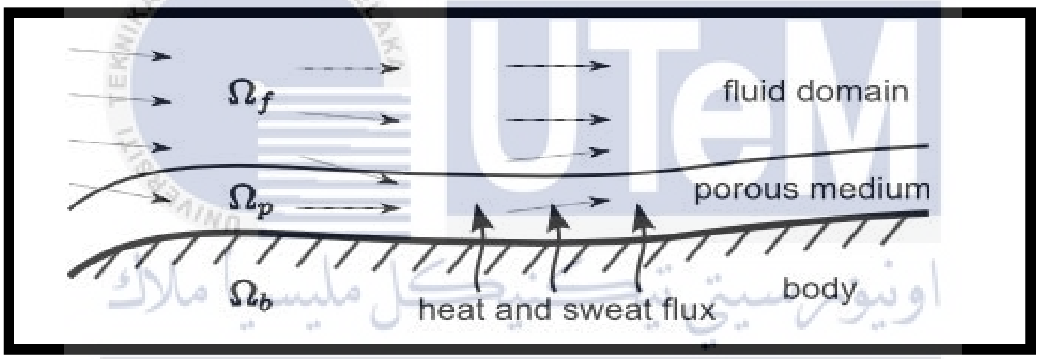


Figure 2.4 Air flow filtrating into a porous tissue

Source: Thorvaldsson.K,(1999)

2.5 Overview of the helmets in the market

Helmets effectively protect heads and reduce both injury risk and severity during motorcycle crashes (Hurt.E,2010). Proper fit and alignment of the helmet on the head are important to optimize head protection. Poorly fitting helmets are prone to move out of position or roll off during a crash and can leave portions of the head unprotected and more vulnerable to injury. Based on a recent study of motorcycle helmet fit found that 40.7% of motorcycle riders wore helmets that were too large and 21.8% wore helmets that were too small.

Based on a study in India, (Mohan.D,1989), wearing helmets is disliked by the riders of motorcycles because of the discomfort caused by the tropical climatic conditions. The Indian Motor Vehicles Act requires all motorcycle riders to wear helmets, but the law is not tightened up in all states in India because of the implement of traffic regulations is state dependent. But few of the big cities (including Delhi) are enforcing the law for riders of motorcycles. Open-face (half-mask) helmets are mostly used than full face (full mask) helmets in India.

Fibre-reinforced plastic (FRP) material used for the outer tough shell of the helmet by a simple hand laying technique because it is most suitable for batch and small scale production. Expanded polystyrene (EPS) is for inner shock absorbing cap but the density and thickness of the material vary from helmet to helmet. Helmets from different brands were gathered and research from the perspective of safety, comfort and convenience in use and also obtain the helmets that can be used in the tropical climate conditions.

2.5.1 Types of helmet

There are few basic types helmets that designed for motorcycling and some of it not intended for motorcycling but used for some riders. All the types of helmets are secured by chin strap and to maintain a snug fit the chin strap will be not fastened.

2.5.1.1 Full face helmet

Based on Wikipedia (https://en.wikipedia.org/wiki/Motorcycle_helmet#Full_face), 2013, the full face helmet in Figure 2.5, covers the whole head and the rear section covers the base of the skull and there is a protective section over the front of the chin. The full face helmets usually designed with the vents to enable the air flows to the riders. The users of this helmet usually don't prefer the heat increasing when wearing the helmet, the sense of isolation, lacking the wind and also the hearing might be reduced. Full face helmets also have an open cutout in a vertical position across the eyes and nose and usually include with a clear or tinted transparent plastic face shield and it is known as visor which is used to access the face of the rider n it does swivels up and down.

The main important attraction of this helmet is their protectiveness. This types of helmets are usually designed for the motocross riders or the off-road riders who usually exclude the face shield but do extend the visor and the chin portions to improve the ventilation process because it is a tough activity which has to be done in on the road or dirt trail which with hills, jumps, sharp turns and often on the muddy terrain. A study concludes that full face helmets give the best protection to the motorcycles riders because 35% of the accidents do give impact on the chin bar area.

Figure 2.5 Types of full face helmet

Source: Ford. D,(2013)

2.5.1.2 Open face helmet

Based on Wikipedia (https://en.wikipedia.org/wiki/Motorcycle_helmet#Open_face), 2013, the open face or better known as “three-quarters” helmet in Figure 2.6 do cover the whole head and the rear section of the skull and also covers the ears and cheeks too but it is lacking covering the chin area of the rider’s face. Nevertheless, the open face helmet has the same protection as the full face helmet but the protection to the face will be less compare to full face helmet if there is an unexpected crash happens. The open face helmet comes with an offer of snap-on visors that can be used by the riders to reduce sunlight glare. Furthermore, the snap-on visor might help the riders from the insects, dust or the wind to the face or any harm to the eyes which cause the rider feel uncomfortable or any injuries to them when they riding from one place to another. Hence, the open face helmets do includes or fitted with a face shield or the snap-on visor which can cover the rider’s face from any harmful incidents happens to their face such as flying insects from entering the helmet.

Figure 2.6 Types of open face helmet

Source: Ford, D. (2013)

2.5.1.3 Half face helmet

Based on Wikipedia (https://en.wikipedia.org/wiki/Motorcycle_helmet#Half_helmet), 2013, half helmet in Figure 2.7 is better known as a “shorty” in the USA and “Pudding Basin” or TT helmet in the UK and it is popular with Rockers and road racers of the 1960s in the British Isles. The half helmet having the same design for the front part as the open face helmet but without a lowered rear near the chin. This helmet looks like the shape of the bowl. This is an open face helmet and we have to wear protective item such as goggles to protect our eyes.

Figure 2.7 Types of half face helmet

Source: Ford, D. (2013)

2.6 Review of thermal effects of headgear

According to (Aare.M,2004), headgear is broadly utilized in both occupation and recreation; it is utilized as an in vogue frill or as a discretionary/compulsory methods for security. Generous research consideration went to improving its defensive capacities. In any case, according (Mohan.D,1993),there is proof that thermal comfort of headgear is problematic in unbiased and warm conditions. To be sure, thermal discomfort is considered as a reason not to wear defensive headgear. Enhancing thermal comfort of headgear is probably going to enhance the eagerness to wear (defensive) headgear, and persuaded an expanding number of studies, of which most were distributed in the most recent decade (Figure 2.8). Additionally, warm situations are of uncommon enthusiasm for comfort impedance, given that headgear builds the thermal protection and will in this way give an advantage in cool conditions. Headgear expands head protection and subsequently is chiefly risky under warm conditions. Since the head is among the most delicate locales for entire body thermal comfort, headgear causes uneasiness and decreases the readiness to wear the headgear under warm conditions. The communication among sweat and material parts of headgear can add to distress. Moreover, there is a connection between appraisals of saw effort and discomfort. Headgear does not influence physiological parameters other than the local skin temperature and local sweat rates.

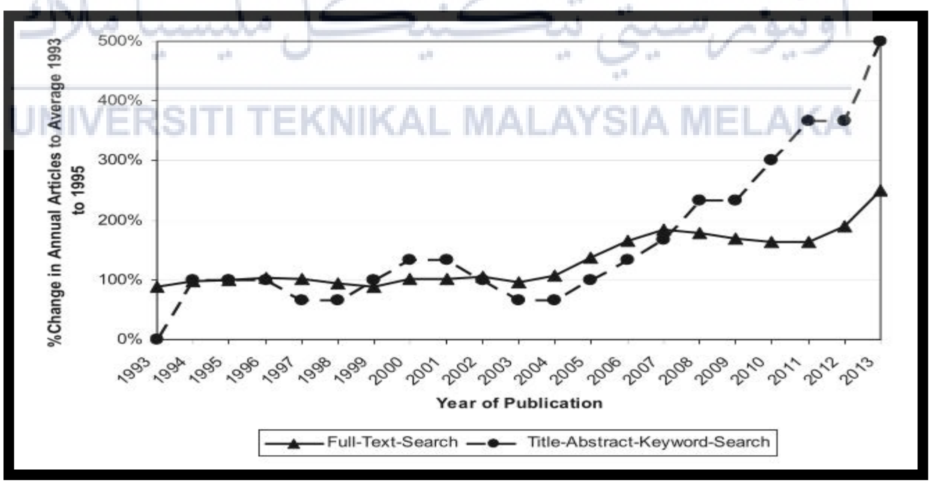


Figure 2.8 Percentage change in annual publications

Source: Aare.M,(2004)

2.7 Material design for motorcycle helmet

According to (Hadj.T,2010), environment protection, and in this manner ecological arrangements, has turned out to be a standout amongst the most vital difficulties looked by the product plan industry and network. In the meantime, there is an unmistakable interest by the buyer for environment well-disposed materials, yet regularly without an expansion in the typical cost. Besides, customers are ending up progressively aware of the comfort given by pieces of clothing that they are wearing. Thus, new strands and textures are developing to fulfil buyer needs. On account of protective wear, well-being helmets are proposed to secure the head against effect or protests tumbling from a stature. Nonetheless, in the hot and humid atmosphere, for example, that in Tunisia, numerous specialists and motorcycles riders are less ready to wear helmets. This is on the grounds that they feel uneasy (ANE 2007).

Thermal discomfort caused by high surrounding temperatures has been altogether inquired about. To enhance helmet use, numerous recommendations to enhance design have been proposed. For example, ventilation openings are appeared to escalate constrained and evaporative convection. Moreover, different qualities of helmets, for example, intelligent materials, colors and general development, have been analyzed and chosen to enhance heat exchange from the human head for nature demonstrated that proposals in the examinations that have been referenced have prompted a few upgrades in the structure of protective headwear. Likewise, helmets materials, for example, extended polystyrene and polycarbonate shell, must be of determined thickness. This is of significance for giving adequate assurance if there should be an occurrence of the effect. The change of the thickness could fundamentally bargain protective helmets security. Along these lines, to upgrade the heat transfer in the protective helmets, the issue of the comfort liner ought to be tended to.

A comfort liner is a layer that dwells between the head and the extended polystyrene layer. XD spacer textures are by and large broadly used to supplant froth in the solace liner of a helmet. Their primary preferences are breathability, protection pressure quality and weight conveyance. Right now, the spacer texture from regular filaments isn't popularized, which can impact purchase decision. Engineered strands are not hydrophilic, in this way dampness sorption is constrained just to the slender activity (XD Spacer Fabric 2011). In this unique situation, we structured a biological comfort liner utilizing, on one hand, characteristic filaments and, then again, phase change material (PCM) as a protective helmets cooling framework. It is proposed that such an item could be utilized by architects and specialists who wish to convey 'green' item decision that can improve any maintainable design.

A helmet more often than not comprises of three essential components, the external shell, an effect liner and a comfort liner as shown in Figure 2.10. The intense external shell secures the head by equitably scattering powers over the inward effect layer. The effect liner ingests the vast majority of the effect vitality by twisting upon effect. At long last, the comfort liner gives a cosy and agreeable fit over the wearer's head (MSF 2002). The head is a noteworthy body region for heat evacuation. The heat that is picked up or lost from the head can be dry or potentially evaporative. At the point when a helmet is worn, dry heat is expelled by convection (through the protective helmet shell and the space between the helmet shell and the head), conduction and radiation. Furthermore, dry heat exchange through conduction is a little part of the heat exchange process. Warmth exchange by vanishing pursues indistinguishable example from convection. Vanishing of the heat from the head happens by the dissipation of sweat created on the head. At the point when the sweating zone of the head is secured, vanishing is impressively decreased. For security reasons, the defensive protective cap shell is impermeable to the two solids and fluids, and thusly counteracts sweat vapour exchange. Evaporative heat exchange can be enhanced just when the protective helmet has great ventilation choices, for example, ventilation openings on the helmet shell and breathable comfort liners as shown in Figure 2.9.

At the point when the protective helmets are worn, the dampness exchange rate is low. Subsequently, the relative and outright moistness dimensions of the microclimate will build, along these lines smothering evaporation of the sweat. The impression of uneasiness relies upon the level of skin wetness. The sweat vapour from the head can be exchanged over the comfort liner leaving the microclimate by ventilation and constrained convection. Then again, for fluid sweating, the instrument by which the drops of sweat are transported in materials is like that of wicking of fluid in vessels. The volume rate at which a fluid travels through a permeable channel is identified with the main impetus which demonstrated that wearing a protective helmet impacts heat exchange properties because of the protecting properties of the helmet materials. Likewise, vitality retention materials secure the head, yet in addition, altogether increment protection because of the required thickness. In this manner, the heat that is normally exchanged by means of convection or radiation to the encompassing condition is held inside the protective helmet, expanding the surface temperature of the skin and head.

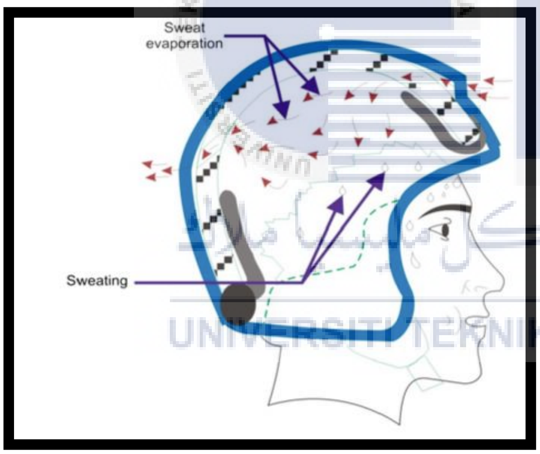


Figure 2.9 Moisturization transfer from head

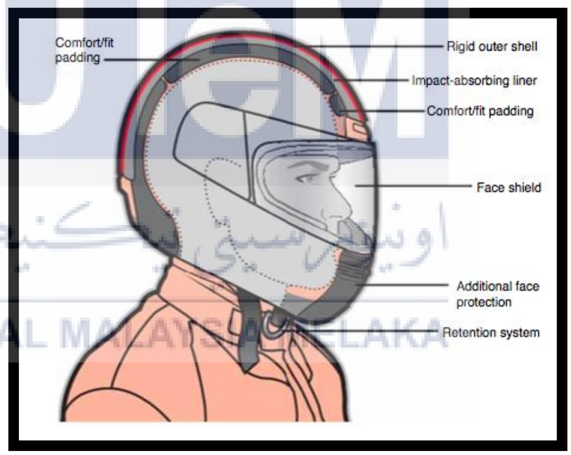


Figure 2.10 Safety helmet components (MSF 2002)

Source: Hadj.T,(2010)

2.8 Forced convective heat loss through full-face motorcycle helmets

It has been proposed that helmet comfort is of decisive importance to riders of powered two-wheelers (PTW) in a warm climate A large study of PTW accidents found 10% of all riders studied did not wear a helmet while riding in traffic (ACEM, 2004). Furthermore, the self-reported helmet usage among teenaged PTW drivers in southeastern Italy in summer was only 35%.This conclusion was drawn for protective headgear in general who found that thermal discomfort reduces the willingness to wear such headgear. Several studies showed increased levels of thermal discomfort caused by protective headgear in warm environments,(Liu.X,1999). There are studies used heat transfer as a basis to optimize protective headgear for thermal comfort and temperature sensation. The previously investigated variations of forced convective heat loss for 27 motorcycle helmets to find large inter-helmet variations in heat transfer at some wind speed using full-face helmet subjected to three factors such as head tilt angle, head form wig-helmet as shown in Figure 2.11 combinations to simulate hair and 10 different wind speeds.

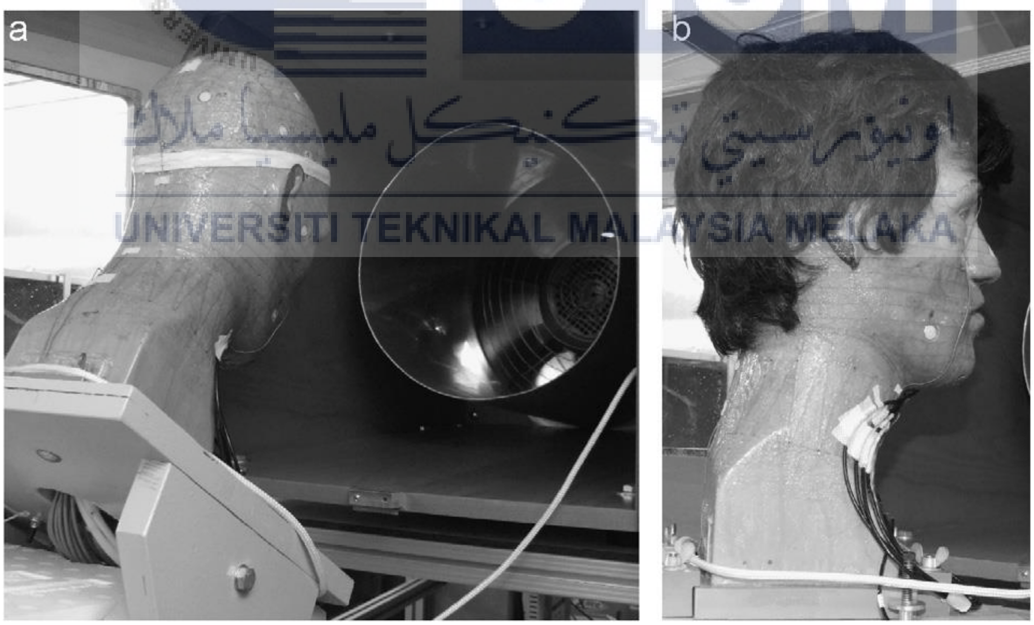


Figure 2 9 Thermal manikin headform

Source : Liu.X,(1999)

There are six modern full face motorcycle helmets tested on a thermal manikin head form and the cross-section of the full face helmet as shown in Figure 2.12. The surface temperature of the headform was stabilized and the power needed to maintain the temperature in a steady state period. The neck part of headform was heated to prevent conductive heat transfer to the support. The support could be rotated enables head tilt for some degrees relative to the wind. The test is being done using a helmet with the involvement of 30° forward tilt (TILT), the wearing of a wig (WIG) and a variation of wind speed (SPEED). The test is conducted assessing the given helmets with all vents open and consecutively all vents closed, or vice versa in random order. The results from TILT and WIG compared to the previous study, (Helman. H,2008). The results of head tilt are the effect of tilt in two manners, by direct comparison. Besides that, wig reduced the heat significantly for all helmets in the face section and for half in the scalp section. The wind speeds show the variation of heat loss in the face section by the fan of the wind tunnel. Most of the helmets reduction in heat loss in the face section found when tilting the head forward. Moreover, adding the wig reduces heat loss caused by the base of the wig. In order for a good understanding of the heat loss, flow patterns and pressure fields, measurements and simulations from a fluid dynamics perspective could be interesting. Comfort is important area yet to be explored and would help guide modifications which help to improve the acceptability of such helmets in warm climates.

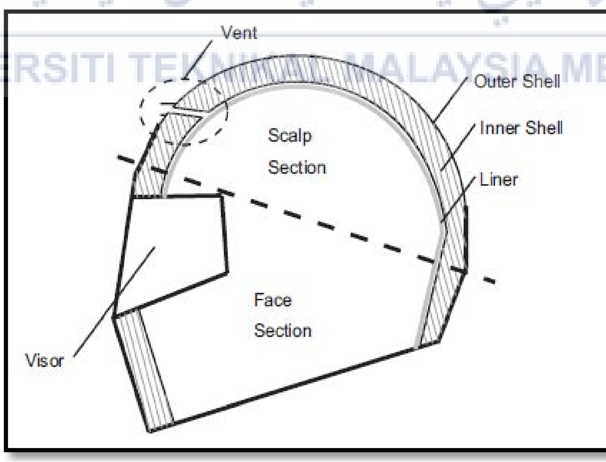


Figure 2.10 Cross section of full face helmet

Source: Helman. H,(2008)

2.9 Temperature perception parameterization for ventilation changes of motorcycle helmet

According to (Bogerd.C,2008), temperature perception and thermal discomfort of headgear have frequently been concentrated with thermal manikin headforms. A basic presumption of these estimations is that of an immediate connection between the thermal impression of subjects and a measure got from such headforms (e.g. warm misfortune, temperature, warm motion, or wind stream). A few researches found that in warm situations the order of headgear dependent on manikin headform estimations is tantamount to the arrangement dependent on temperature recognition or thermal comfort by human subjects. We find that subjects can efficiently see impacts caused by changing the vent setup of motorcycle helmets, under reenacted riding conditions. Moreover, the principle determinant of the reaction conduct of the subjects was the vent-incited warm misfortune. Be that as it may, the connection between vent-prompted warm misfortune and reaction conduct differed among the helmets. The number of responses for temperature perception for the scalp section with respect to vent-induced heat loss for helmets as indicated. The dashed lines indicate the value of corresponding to the mean response for all helmets combined, for each response category as shown in Figure 2.13.These outcomes affirm that a warm manikin headform is a helpful device for examining and upgrading temperature impression of headgear.

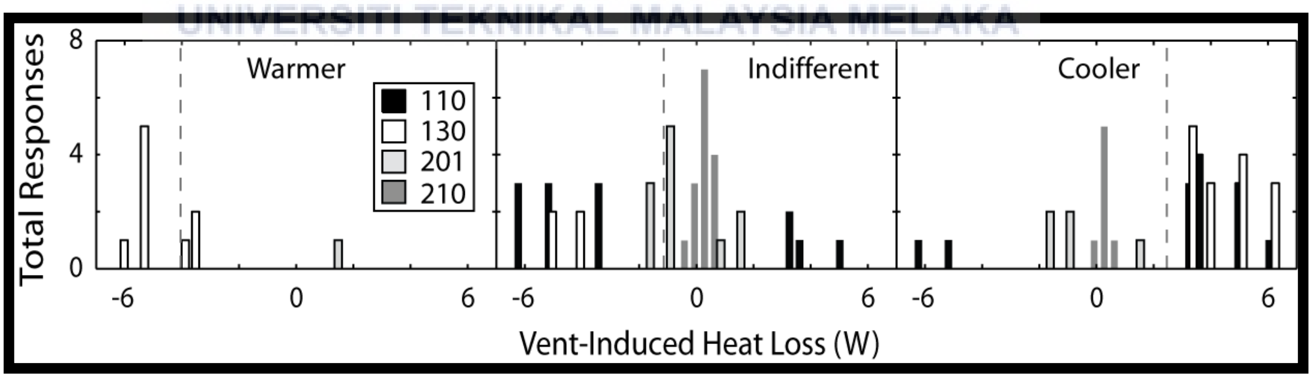


Figure 2.11 Vent-Induced Heat Loss (W)

Source: Bogerd.C,(2008)

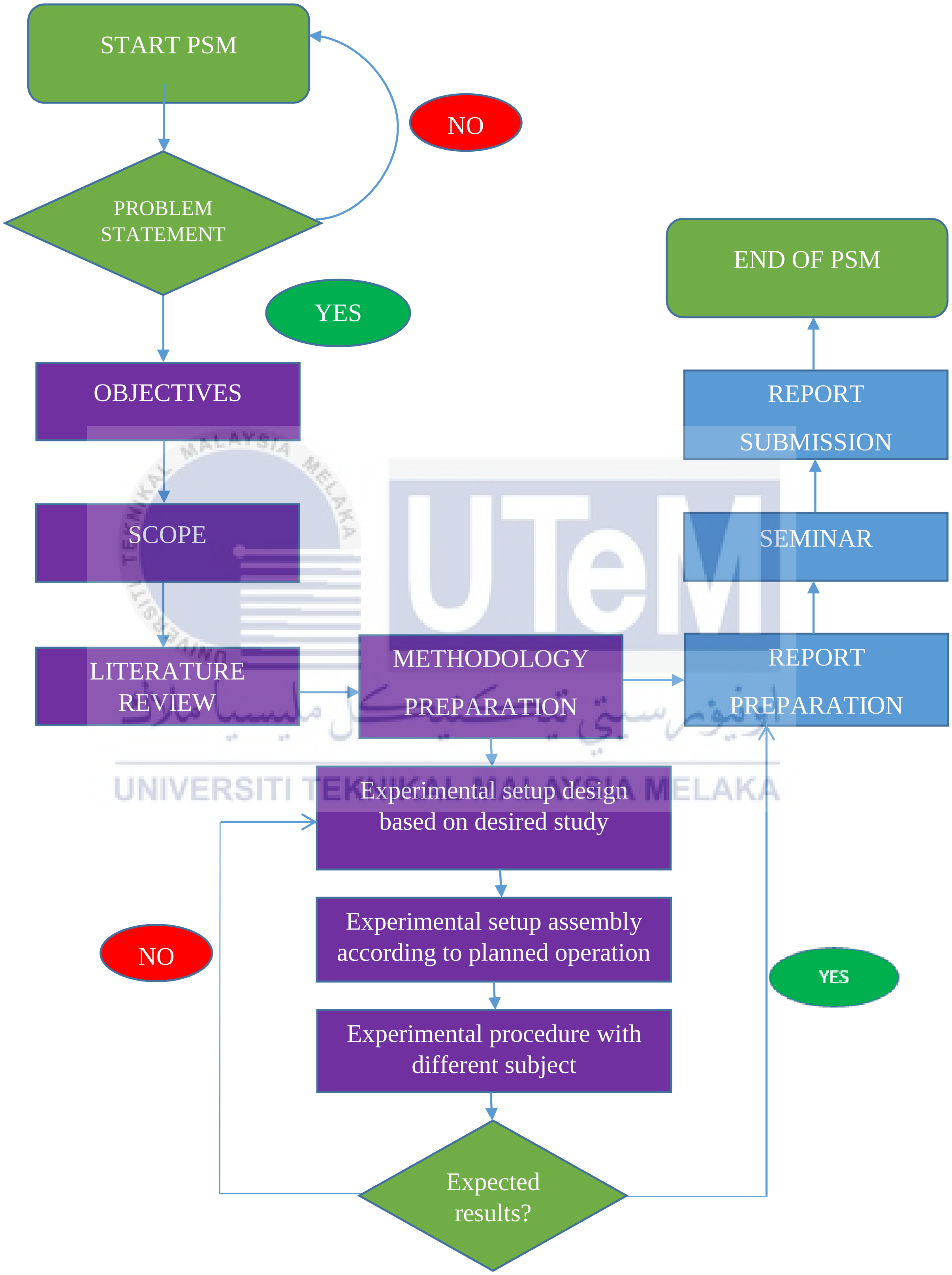
CHAPTER 3

METHODOLOGY

3.1 Introduction

In this research, thermal comfort as the main objective of the experiment. In order to achieve the objectives mentioned earlier, it will require the sets of the working steps which need to obey thoroughly throughout this chapter. The steps and processes that will follow towards the development of this study will be clearly stated as a form of the flowchart as an overview of this overall experiment and also how the development on thermal comfort of the motorcycle helmet user. This chapter will begin with the overall project flowchart that will guide throughout this project in order to discuss the sequence of the project.

3.2 Overall flow chart



3.3 Overall gantt chart

PROJECT TITLE : STUDY ON THERMAL DISCOMFORT OF A MOTORCYCLE HELMET USER																
	Sep-18				Oct-18					Nov-18				Dec-18		
	03–07	10–14	17–21	24–28	01–05	08–12	15–19	22–26	29–02	05–09	12–16	19–23	26–30	03–07	10 – 14	17– 21
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
Project Stages																
Title Selection																
Selecting PSM title from potential supervisor																
Getting approval on the title selected																
Literature Review																
Identification of problem statements, scopes and objectives																
Research on related documents, ex:journals,books,etc																
Methodology																
Research on the existing helmets on market																
Preparation of methodology and strategies																
Selection of materials and equipments needed																
Analysis on project costs and material supply																
Documentation																
Draft Report (PSM1) preparation and submission																
Evaluation																
Seminar-Presentation																

3.4 Chronology of project

There are important aspects such as objectives, scope, and problem statement is established in order to ensure proper flow of the project. The fulfilment of the project depends on the objective, problem statement and scope of the project and the completion of the project depends on every stepping stone that will be crossed throughout the study. Objectives for this project is fixed to enhance the understanding of the thermal comfort based on the motorcycle helmet user and the amount of heat transfer from that particular subject. Besides that, before the kick-off of the project, it is important to understand the main points and the detailed description on the research done before with the assist of the assessment of the journal and research papers. They provide a better and general idea of the previous study and researches and also the future study that should be done for better knowledge.

Besides that, it is necessary to determine the experimental setup for the subject to conduct the study. Therefore, an experimental setup needs to be created in order to conduct the study as per required. The important parts and materials which need to make up the project is listed and assembled. The project then will undergo the modification and fabrication process. After that, the test rig section will take place which will differentiate the amount of the heat transfer from a subject's head to the helmet. Once the system is prepared, the experiment will be conducted with the subject. Then, the results and data collection will take place. Moreover, the experimental procedure will be repeating again by using another subject's head in order to produce the data. The results will differ cause of changes in the size of head and body temperature of a subject that will release through the helmet. The mandatory parameters will be noted and will be recorded. The parameters such as body temperature, the surrounding temperature, the speed of the cycling will be observed and reading will be taken. Based on the data collected, interpretation and analysis of the data will takes place by comparing the manipulating factor in the test.

3.5 Parts and materials

Parts and materials used for the experimental purpose for the study of thermal discomfort of the motorcycle helmet user will be listed in this section. The purpose and the usage of the parts and materials will be explained thoroughly as well.

3.5.1 Helmet

There are three types of the helmet in Figure 3.1, 3.2, 3.3 used to develop the test rig to obtain thermal moisture mapping of the motorcycle helmet user. Type A helmet is with the ventilation holes, type B is with manufacturing ventilation holes and type C is with no holes. The ventilation holes are for the air to go through to maintain the level of humidity and the temperature. The subjects will be tested using this helmet to measure the humidity and the temperature.

3.5.1.1 Type A

Figure 3. 1 Type A

3.5.1.2 Type B

Figure 3. 2..Type B

3.5.1.3 Type C

Figure 3. 3 Type C

3.5.2 Micro sensors

SHT7X is Sensirion's family of relative humidity and temperature sensors with pins as shown in Figure 3.5. The sensors integrate sensor elements plus signal processing in a compact format and provide a fully calibrated digital output. A unique capacitive sensor element is used for measuring relative humidity while a band-gap sensor measures temperature. These cables in Figure 3.4 will connect to the data logger to record the readings of the relative humidity and temperatures.

Figure 3. 4 Sensor cable with RJ45 plug

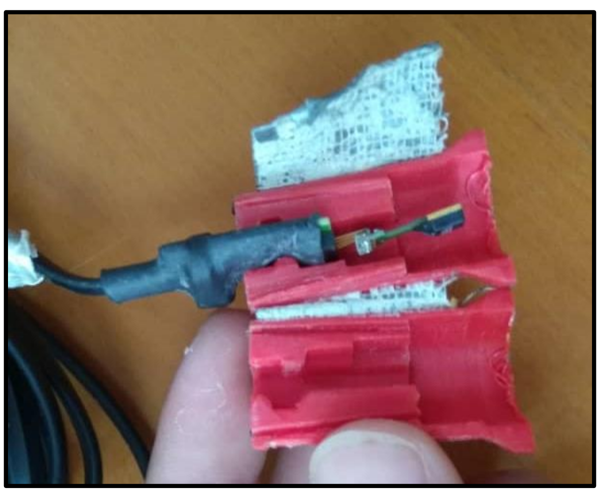


Figure 3. 5 SHT7X Sensor

3.5.3 Data logger

The data logger kit EK-H4 shown in Figure 3.6 is made for running Sensirion's temperature and humidity sensors and display measured values. It is able to communicate with SHT7X display the measurement values on a display on the multiplexer. The main purpose of the data logger or called an evaluation kit is to exhibiting the exceptional execution of Sensirion's humidity and temperature sensors with no possess hard or programming configurations work.

Figure 3. 6 Data logger

3.5.4 Computer

Regarding a PC as shown in Figure 3.7 and explicit programming provided with the evaluation kit, it might likewise be utilized as a data logger for straightforward test estimations. The multiplexer with 4 ports is associated with the PC through the USB interface. The product may record and show the humidity and temperature values and additionally determined estimations of dew point and power utilization. Different multiplexer boxes with sensors might be controlled by the same programming crosswise over different USB interfaces. It will form a table and record all the values based on the interval time that set on the software.

Figure 3. 7 Computer

3.5.5 Indoor exercise bicycle

An indoor exercise bicycle shown Figure 3.8 or called a stationary bike is generally an exceptional reason practice machine looking like a bike without wheels. It is likewise conceivable to adjust a standard bike for stationary exercise by setting it on bike rollers or a coach. Rollers and mentors are frequently utilized by hustling cyclists to warm up before dashing or to prepare alone machines inside. In our case, we are using it for the subject to pedal it and warms up their self and release heat from the head and body to measure the level of humidity and the temperature.

Figure 3. 8 Indoor Exercise Bicycle

3.6 Data measurement

For test purposes, certain information is required to be estimated previously and amid the trial. These information display the framework's execution dependent on parameter observed. Estimated information includes relative humidity, temperature, dew point and absolute humidity. The following table 3.2 shows instruments will be utilized for estimation of the following parameters.

Table 3.1 Instruments for the measuring the parameter

Parameter	Instrument	Unit
Relative Humidity	SHT 7X sensor	RH[%]
Temperature	SHT 7X sensor	Celcius (°C)
Dew Point	SHT 7X sensor	Celcius (°C)
Absolute Humidity	SHT 7X sensor	[g/m3]

3.7 Experimental procedures

There are three types of helmet use for testing using a number of healthy subjects for the experiment. The helmets which are used for testing will be a standard adult size which is large. The head size will be differ based on each subject's head size as shown in table 3.3. In the test rig section, indoor exercise bicycle placed in a room temperature area and the experiment will be carried out. The microsensor placed in a few places on the helmet to measure the humidity and temperature of the subject's head. The microsensor connects to a data logger using an RJ45 plug to measure the relative humidity and temperature. Next, the data logger connects to a computer to record the readings of the relative humidity and the temperature.

Besides that, subjects placed on the indoor exercise bicycle and start to pedal it. The subjects need to wear the type of helmets and sit on the indoor exercise bicycle and start the testing. It makes the subject to start sweating and feels warm and the heat from the head of the subject transfer to the helmet and the sensor will detect and start to measure the relative humidity and the temperature. The sensor will send the information to the data logger and from the data logger, it will transfer the data to the computer as a graph and table form based on the interval time that has been set up earlier. The data will be analyzed and tabulate depends on the results that have been recorded. The steps will repeat for other helmets to measure the relative humidity and the temperature of the subjects. The thermal discomfort of the motorcycle helmet will be evaluated by the subject based on their comfort in a survey form that will be provided.

Moreover, there is a total of seven number of sensors that need to be considered. There are six sensors need to be fixed on the helmet and another one will be attached to the ambient temperature to record the readings. The sensors will be fixed on the front section, back middle section, lower back section. The schematic diagram of the helmet with the sensors will be shown in Figure 3.9, 3.10 and 3.11 below. Table 3.3 shows the sensor location on the helmet.

Table 3.2 Sensor location on the helmet

Area	Sensor location
Front	Sensor 1
Center right	Sensor 2
Top	Sensor 3
Back right	Sensor 4
Back left	Sensor 5
Lower back	Sensor 6
Ambient	Sensor 7

Table 3.3 Head size for each of the human subjec

Subject	Head breath (cm)	Head width (cm)	Circumference (cm)
Saras	19	15	56
Asyraf	20	16	57
Akram	19	18	57
Rais	21	16	58
Joeshua	23	16	59

3.7.1 The view of the helmets

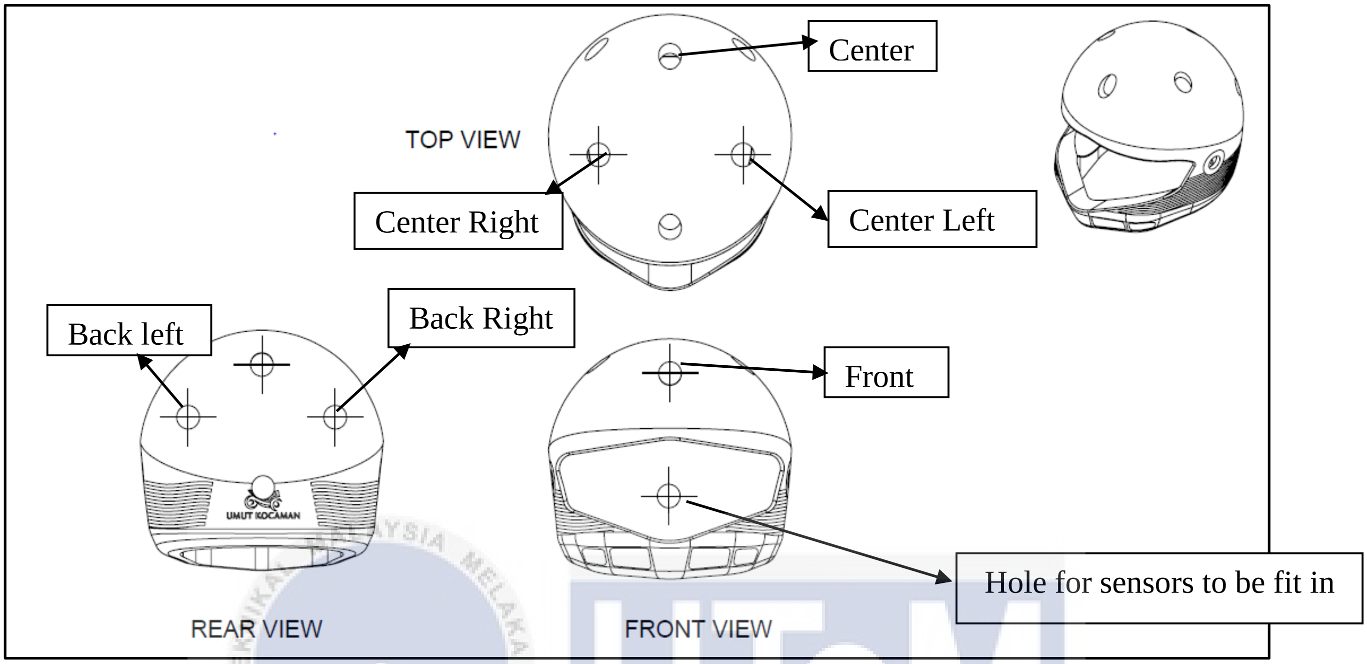


Figure 3. 9 3D view of the helmet

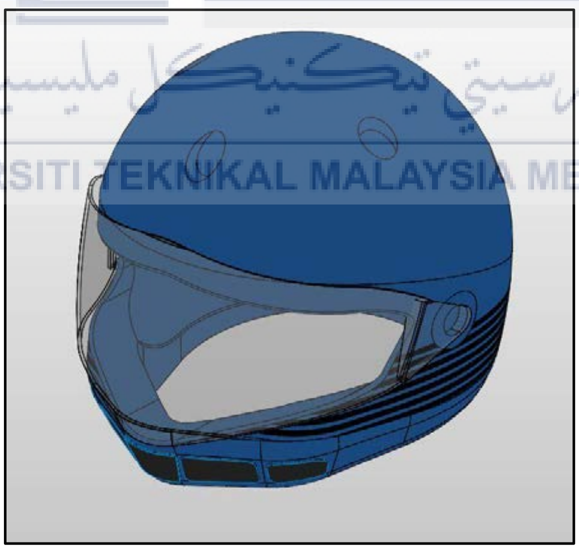


Figure 3. 10 Overall view of the helmet

CHAPTER 4

RESULT AND DISCUSSION

4.1 Experimental Setup

An experimental setup is developed as shown in the Figure 4.1. Test rig mainly developed to measure multi-point temperature and the relative humidity inside a motorcycle helmet using micro sensors. All the micro-sensors were fitted on the each type of helmets which is type A, type B and type C and there are seven position of sensors. There are front, center, center right, lower back, back right, back left and ambient positions. The human subjects will undergo testing for 30 minutes by wearing the helmet with micro-sensors and sitting on exercise bicycle and pedal it. The subjects had rest for first 5 minutes and another 5 minutes in middle of the testing. The readings were tabulated through thermocouples with micro-sensors to data logger and it connected to a computer. The readings were observed and measured and a graph for each position of sensor for the each type was plotted and overall graph was plotted for each of the type. Figure below shows the experiment for all the types of helmet for thermal discomfort of a motorcycle helmet user.

Figure 4.1 Experiment setup

4.2 Data and results

4.2.1 Results for subject 1

<u>Temperature vs time graph</u>

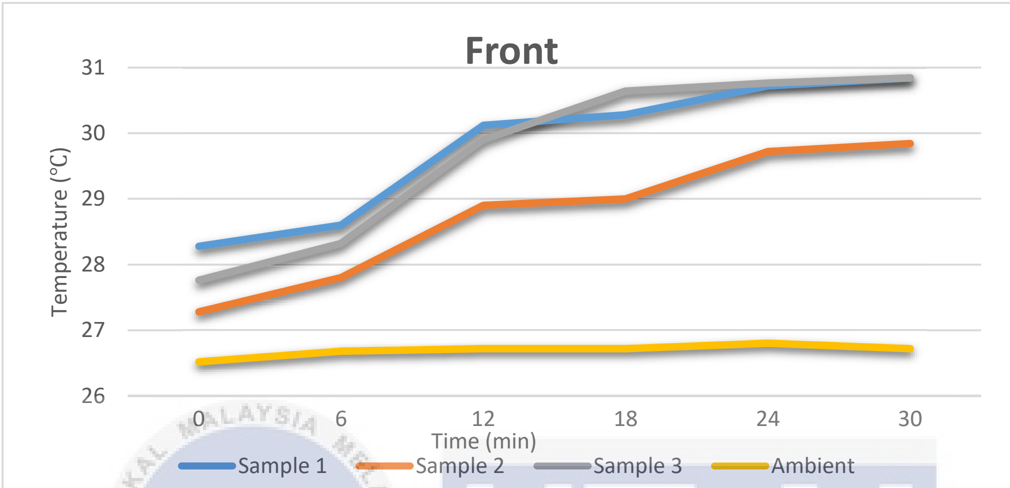


Figure 4.2 Front position sensor for temperature graph

<u>Relative Humidity vs time graph</u>

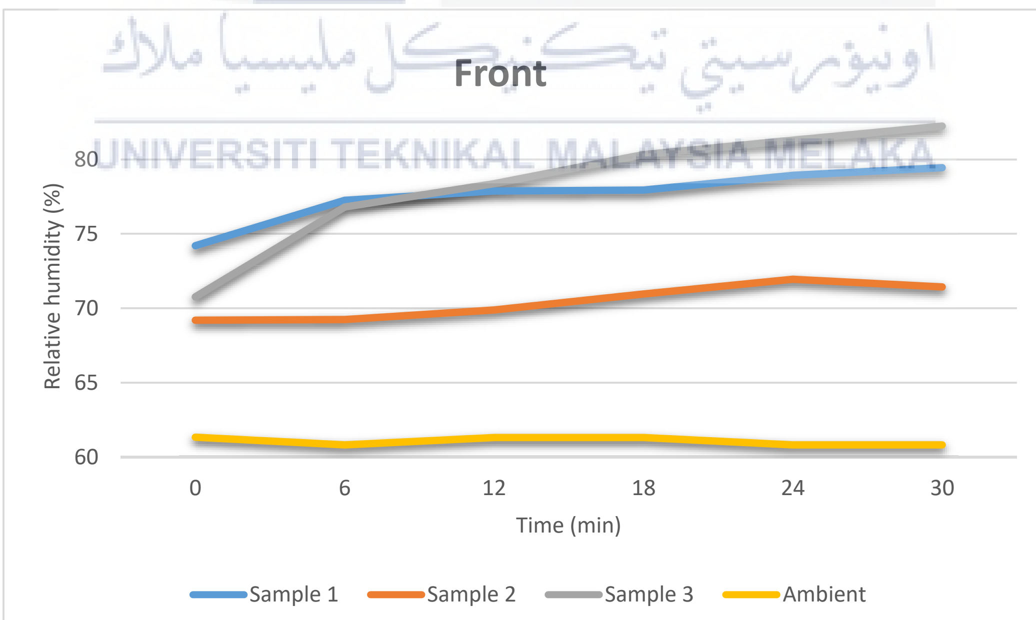


Figure 4.3 Front position sensor for relative humidity graph

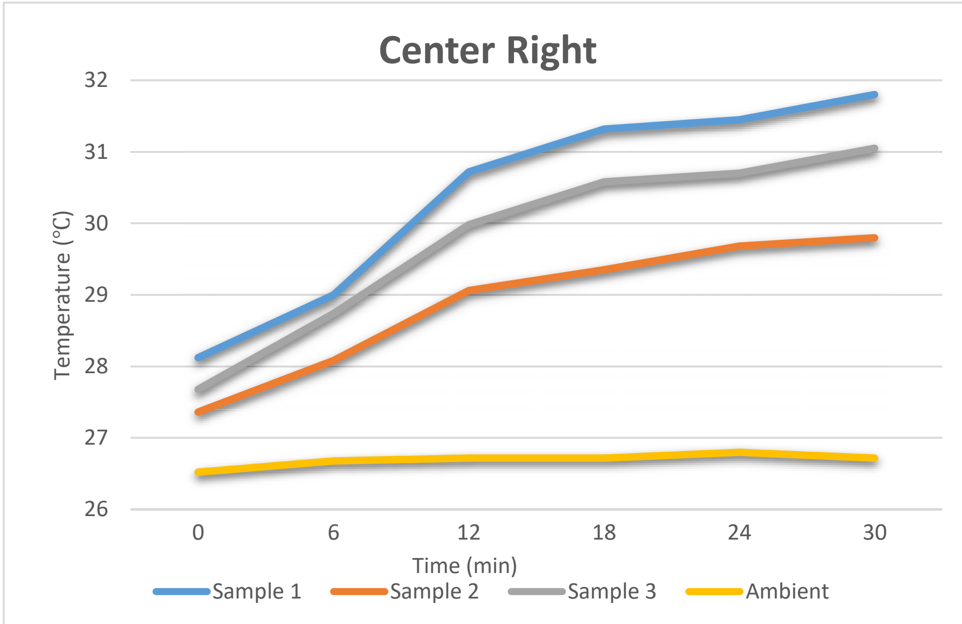


Figure 4.4 Center right position sensor for temperature graph

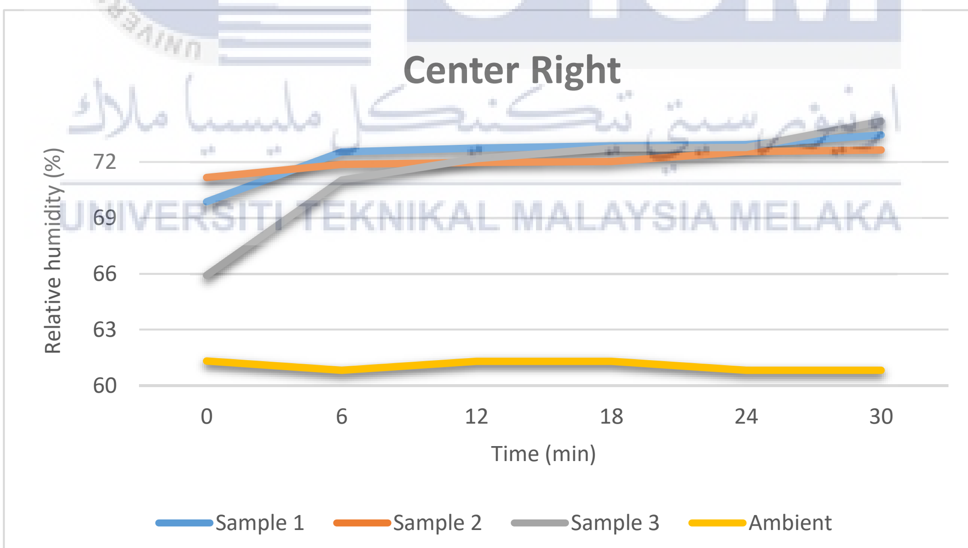


Figure 4.5 Center right position sensor for relative humidity graph

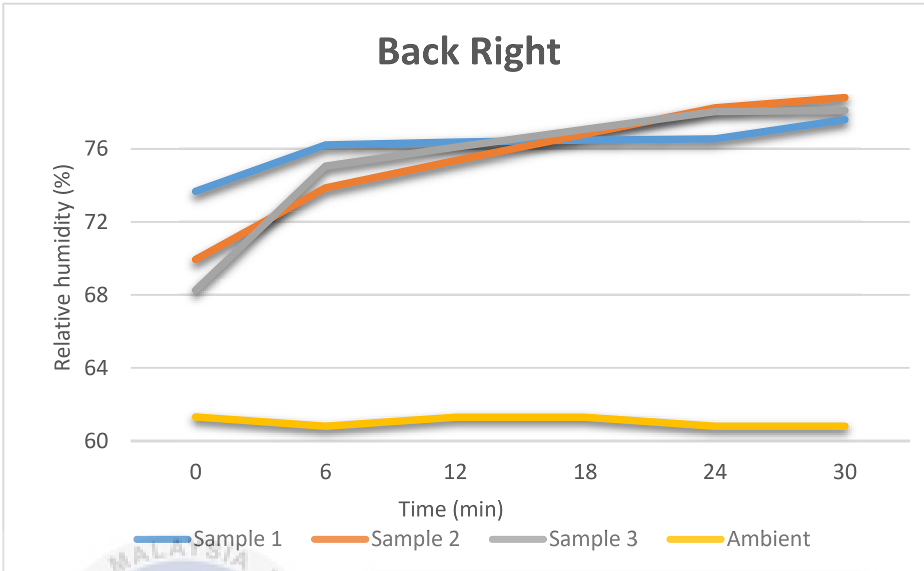


Figure 4.6 Back right position sensor for temperature graph

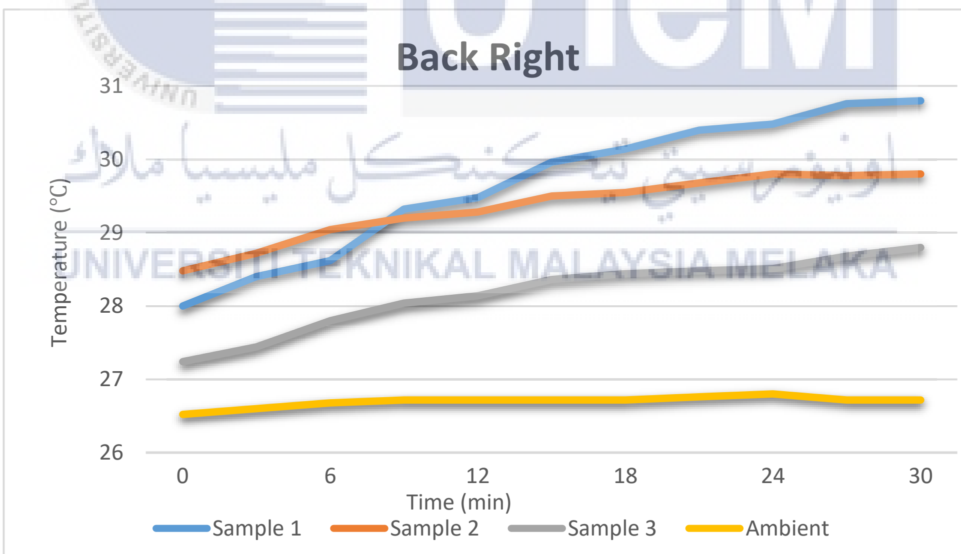


Figure 4.7 Back right position sensor for relative humidity graph

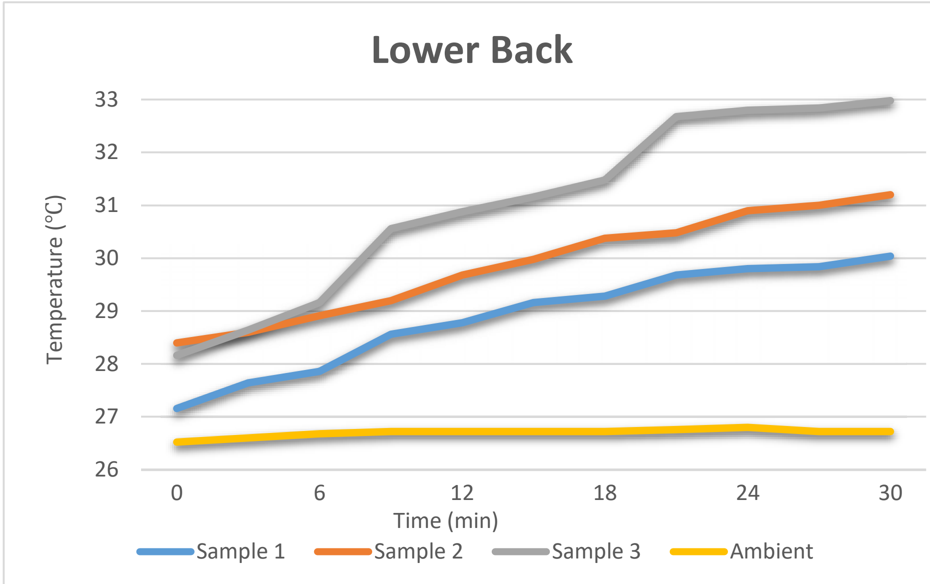


Figure 4.8 Lower back position sensor for temperature graph

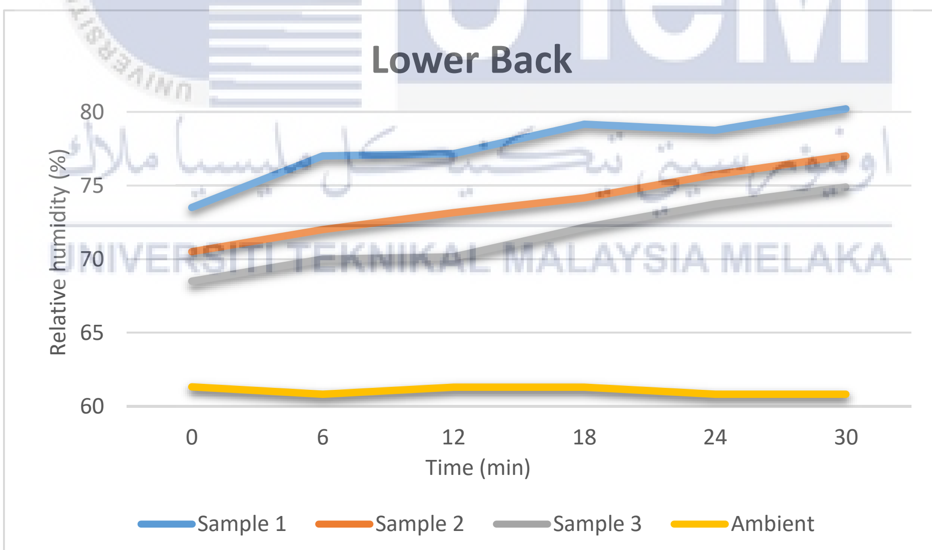


Figure 4.9 Lower back position sensor for relative humidity graph

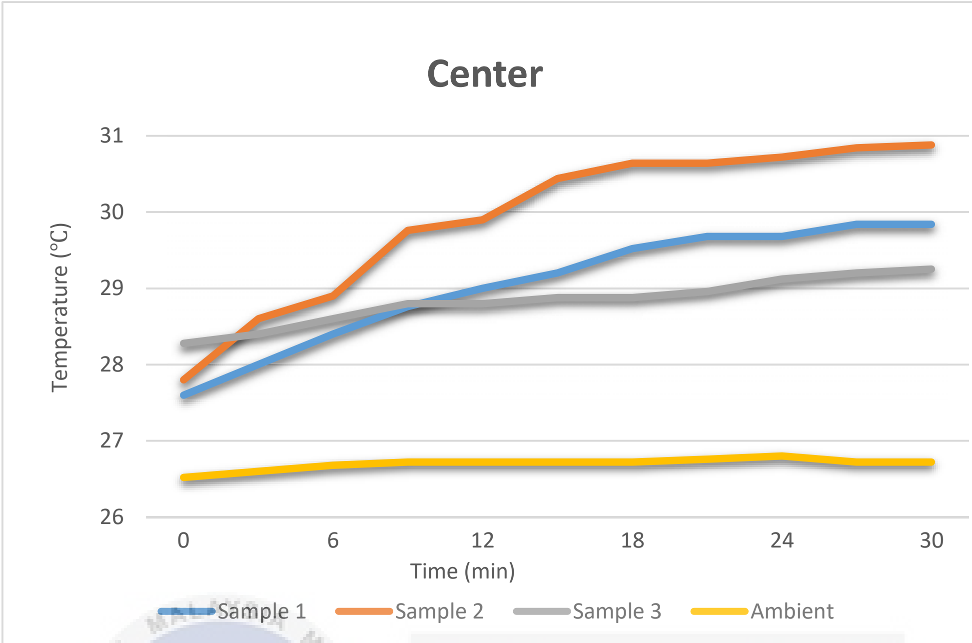


Figure 4.10 Center position sensor for temperature graph

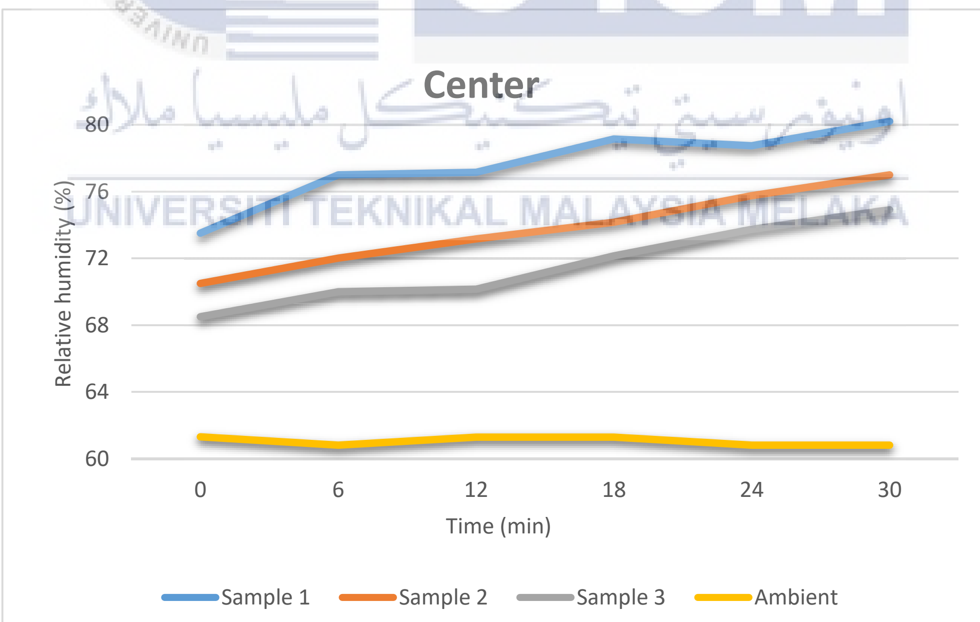


Figure 4.11 Center position sensor for relative humidity graph

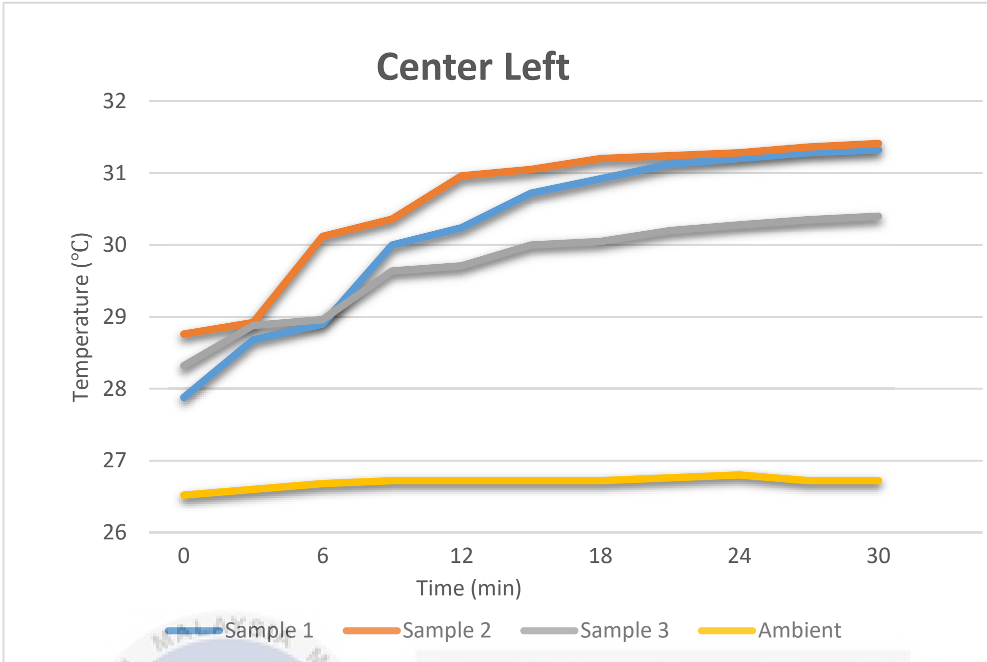


Figure 4.12 Center left position sensor for temperature graph

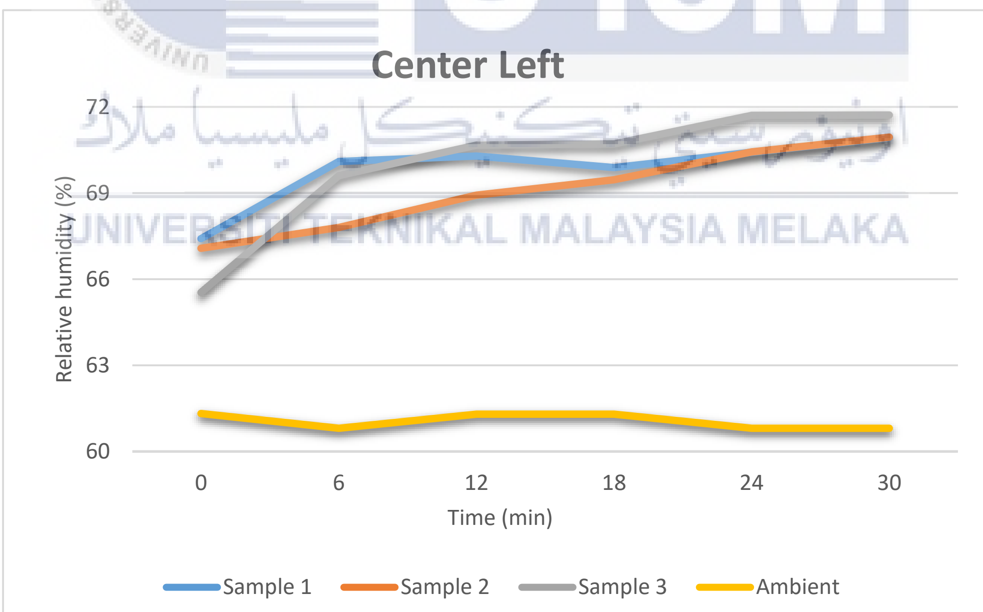


Figure 4.123 Center left position sensor for relative humidity graph

Human Perception

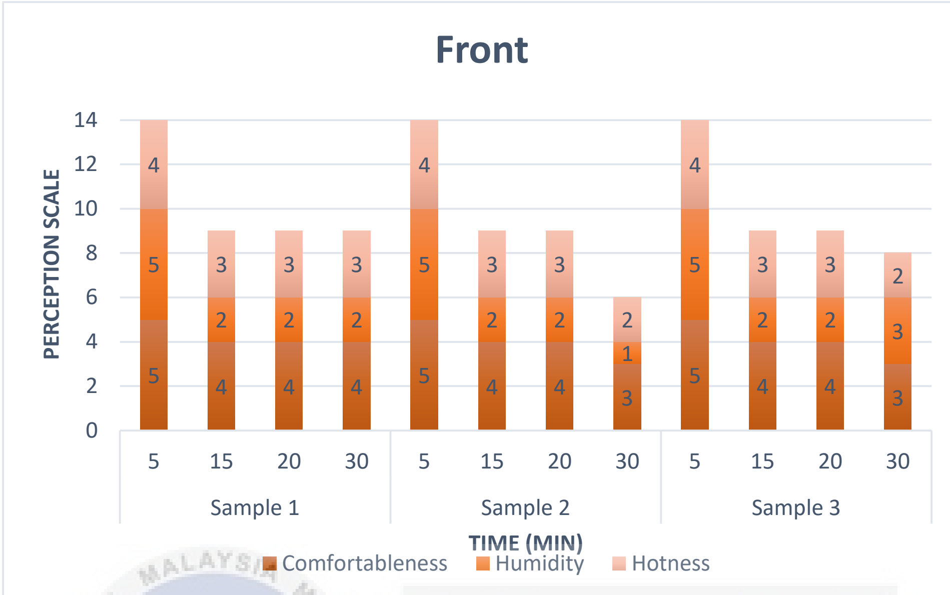


Figure 4.13 Human perception scale for front position sensor

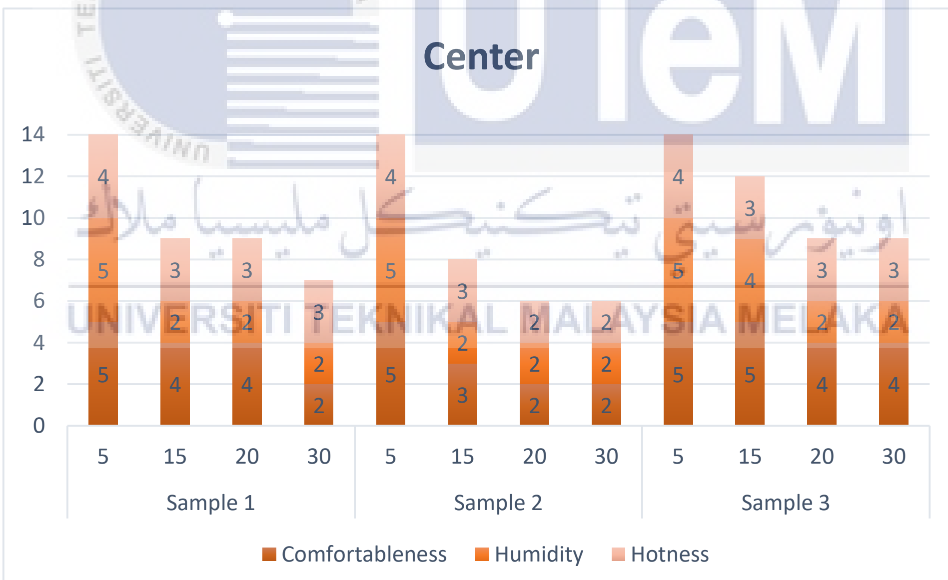


Figure 4.14 Human perception scale for center position sensor

	1	2	3	4	5
A	Most uncomfortable	Little uncomfortable	Moderate	Little comfortable	Most comfortable
B	Most humid	Little humid	Moderate	Little dry	Most dry
C	Very hot	Hot	Moderate	Cold	Very cold

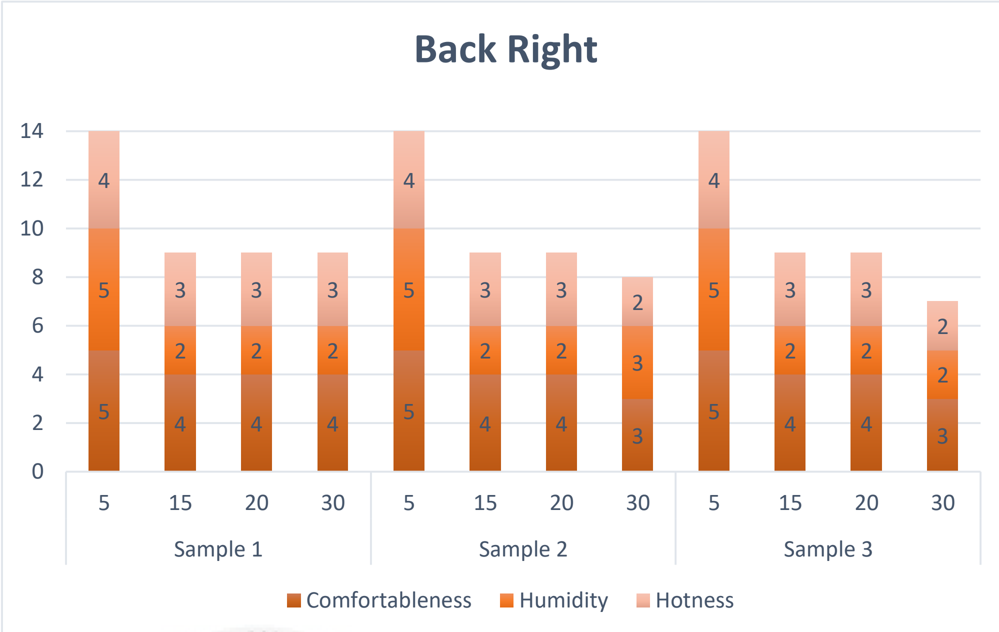


Figure 4.16 Human perception scale for back right position sensor

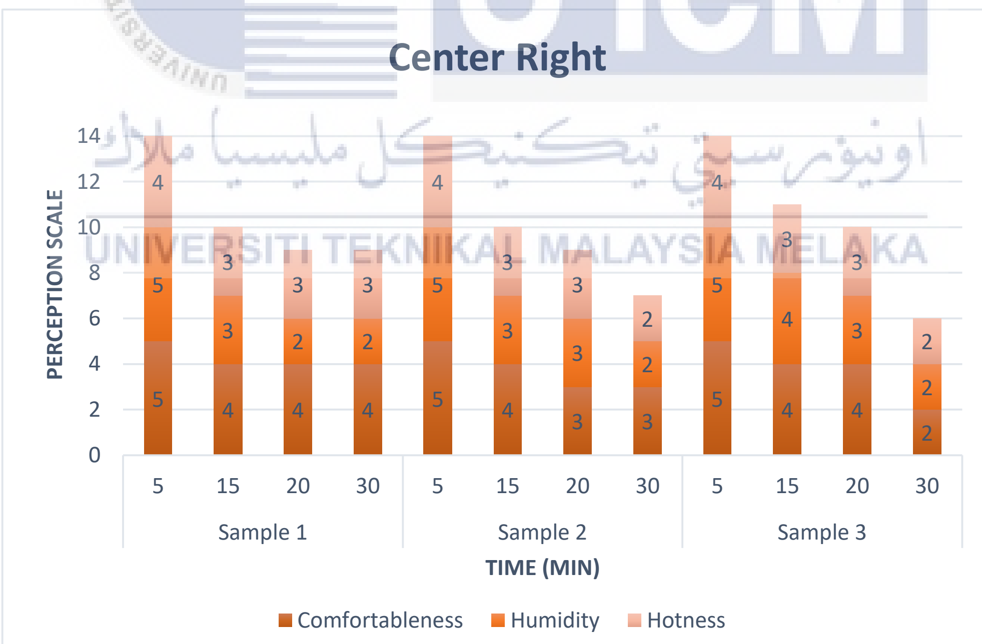


Figure 4.17 Human perception scale for center right position sensor

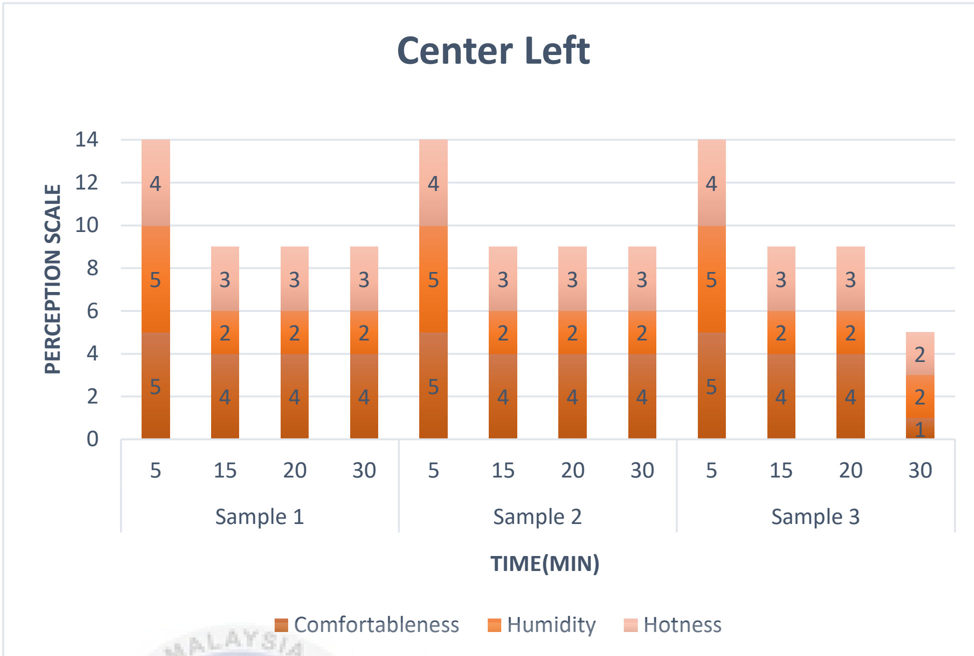


Figure 4.18 Human perception scale for center left position sensor

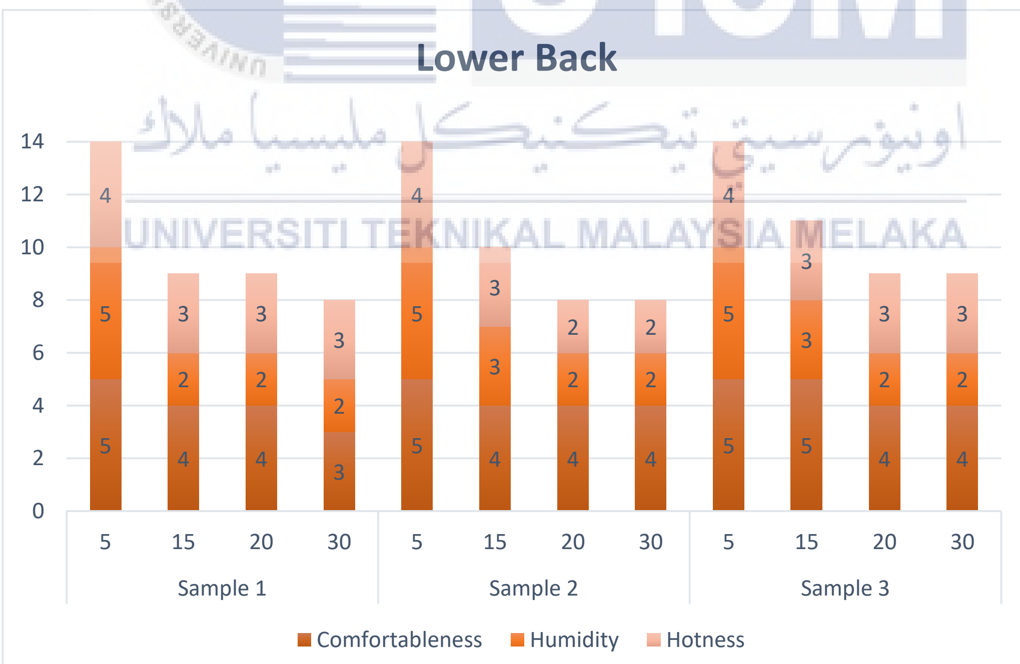


Figure 4.19 Human perception scale for lower back position sensor

4.3 Discussion

4.3.1 Overall average temperature and relative humidity graph for each type

4.3.1.1 Type A helmet

<u>Temperature vs time graph</u>

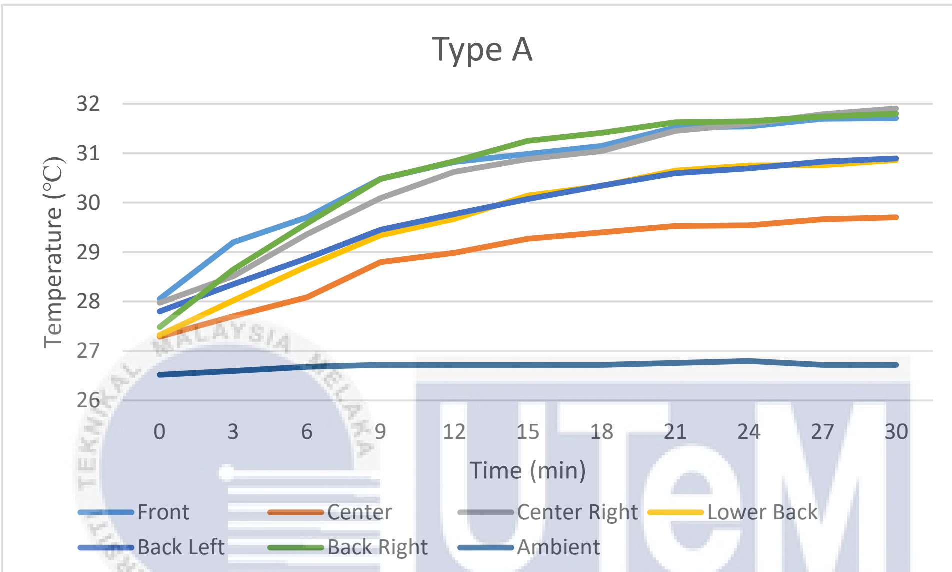


Figure 4.15 Overall average temperature graph for type A helmet

<u>Relative Humidity vs time graph</u>

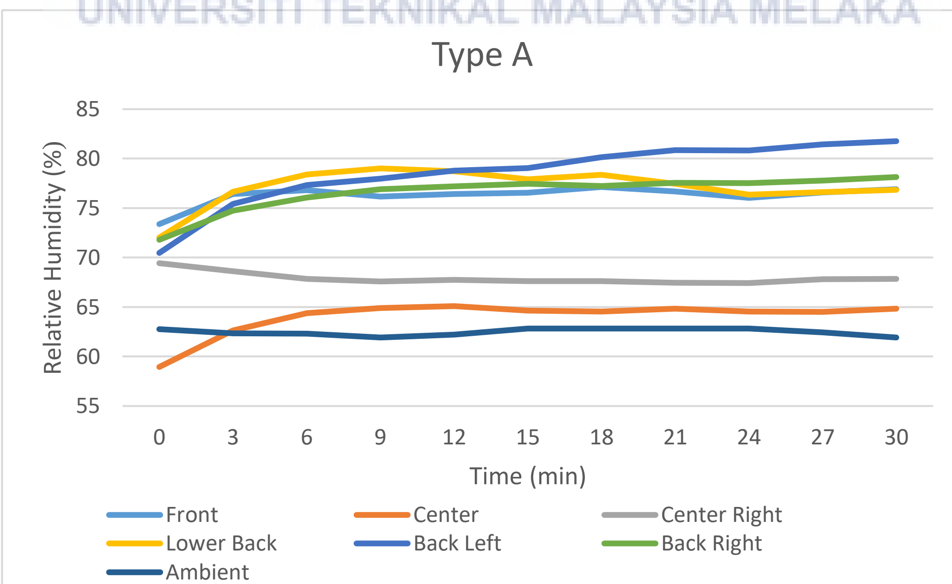


Figure 4.16 Overall average relative humidity graph for type A helmet

The type A helmet is a full face helmet used for the experiment. Figure 4.20 above describes the overall average relationship between time and temperature for each position of the sensor for all the subjects for the type A helmet which is tested in the experiment. The head size which is tested is between 55cm to 60cm. Besides that, figure 4.21 shows the overall average relationship between time and relative humidity for each position of the sensor for all the subjects for type A helmet. Each of the testing for each subject using type A helmet was conducted for 30 minutes and readings were observed.

From the graph in figure 4.20, the front and center position sensor measured the high value of temperature from the beginning of the experiment and it increases constantly until it reaches a constant temperature. Back left and back right sensors are almost beginning at the same temperature increasing simultaneously compare to other positions of sensors and reach a constant temperature. Lower back sensor records at low temperature at the beginning of the experiment and it does increase slowly to reach a constant temperature. The center right sensor had the minimal value of the temperature at the beginning of the experiment compared to other sensors and it reaches its constant value lower compare to other sensors. The ambient sensor records a constant value of temperature throughout the experiment.

Furthermore, the center position sensor records quite high relative humidity value at the beginning of the testing from the graph in figure 4.21 and reaches its constant relative humidity value at the end of the experiment. Front and lower back position sensors almost record the same value of relative humidity value throughout the experiment and reach its constant value at the end of the experiment. Back left position sensor measures moderate relative humidity and it ends with quite high values of relative humidity compared to other position of sensors. The center right position sensors measured a constant value of relative humidity throughout the experiment. The back right position sensor begins with a low value of relative humidity and ends with a constant value which lower than other sensors. The ambient sensor measures a constant relative humidity value throughout the experiment.

4.2.2.2 Type B helmet

<u>Temperature vs time graph</u>

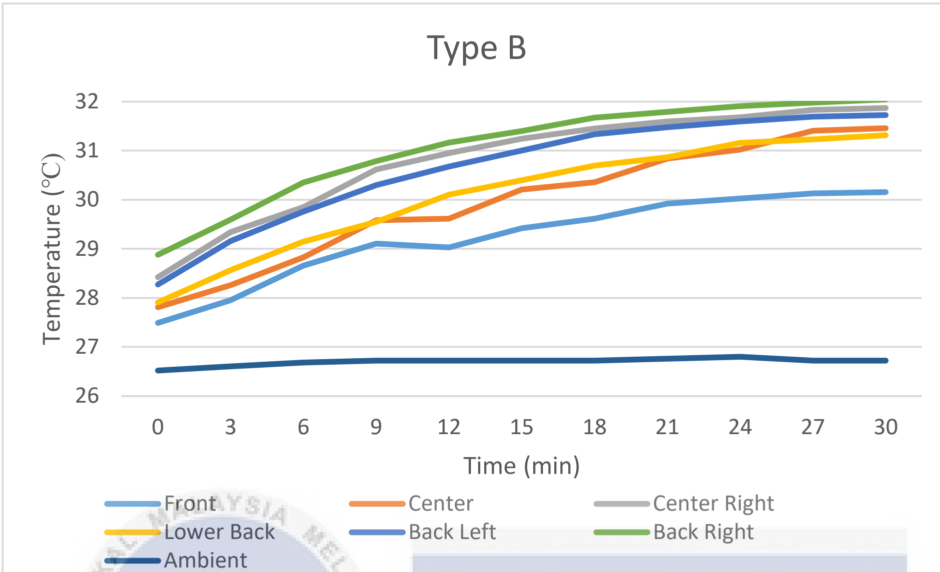


Figure 4.17 Overall average temperature graph for type B helmet

<u>Relative humidity vs time graph</u>

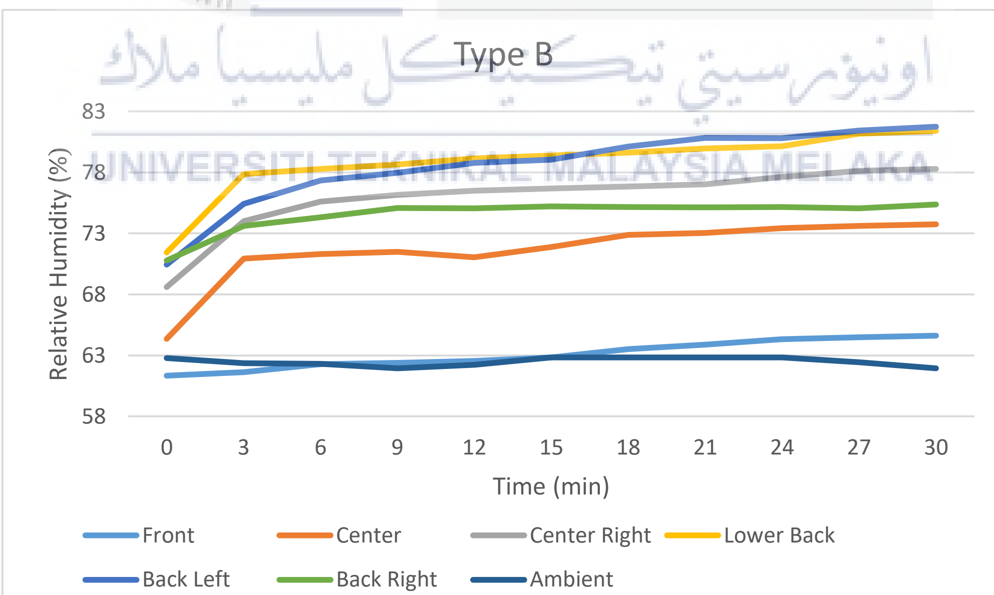


Figure 4.18 Overall average relative humidity graph for type B helmet

The type B helmet is an open face helmet used for the experiment. Figure 4.22 above describes the overall average relationship between time and temperature for each position of the sensor for all the subjects for the type A helmet which is tested in the experiment. The head size which is tested is between 55cm to 60cm. Besides that, figure 4.23 shows the overall average relationship between time and relative humidity for each position of the sensor for all the subjects for type A helmet. Each of the testing for each subject using type A helmet was conducted for 30 minutes and readings were observed.

From the graph in figure 4.22, front position sensor records a lower temperature at the beginning of the experiment and ends at the constant lower value of temperature compare with other position of sensors. Center position sensor holds lower value at the beginning of the experiment and increases rapidly with the constant temperature at the end of the experiment. The back right position sensor begins with a high temperature and ends with the constant value of temperature at the end of the experiment. The back left position sensor holds almost the same value from the beginning of the experiment and ends with a constant value of temperature. Back right position sensors begin at low temperature and end with a higher constant temperature compare with the center right, back left and lower back position sensors. The center right position sensor holds the almost same value of temperature as the lower back position of the sensor and it ends almost value with the front position sensor. The ambient position sensor holds constant value throughout the experiment.

Besides that, the front sensor in the relative humidity graph shown in figure 4.23 holds lower value and ends with a constant value at the end of the experiment. The center position sensor records low relative humidity at the beginning and it continues to increase slowly with the constant value at the end of the experiment. The back left position sensor increase slowly throughout the experiment and reach its constant value at the end of the experiment. Lower back position sensor holds a lower value of relative humidity at the beginning of the experiment and increasing continuously with a constant value. Back right and center right position sensor places quite lower temperature at the beginning and it increases slowly to reach its constant value of relative humidity. The ambient sensor holds a constant relative humidity throughout the experiment.

4.2.2.3 Type C helmet

Temperature vs time graph

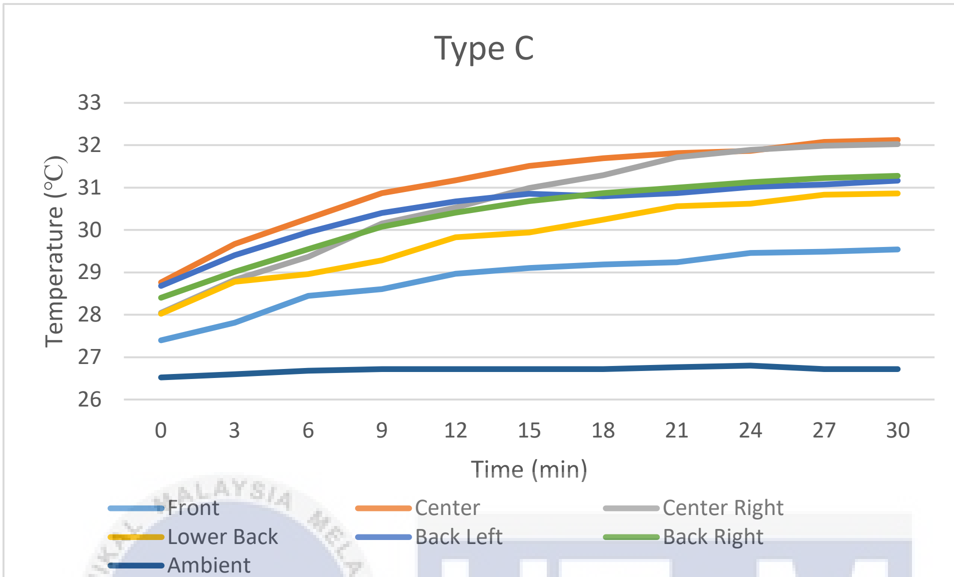


Figure 4.19 Overall average temperature graph for type C helmet

Relative humidity vs time graph

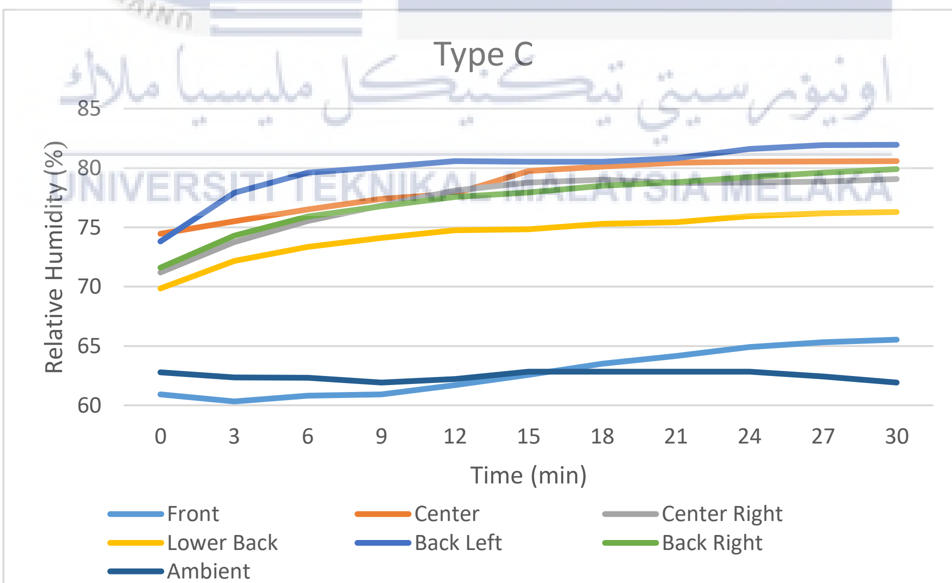


Figure 4.20 Overall average relative humidity graph for type C helmet

The type C helmet is a half face helmet used for the experiment. Figure 4.24 above describes the overall average relationship between time and temperature for each position of the sensor for all the subjects for the type A helmet which is tested in the experiment. The head size which is tested is between 55cm to 60cm. Besides that, figure 4.25 shows the overall average relationship between time and relative humidity for each position of the sensor for all the subjects for type A helmet. Each of the testing for each subject using type A helmet was conducted for 30 minutes and readings were observed.

From the graph in figure 4.24, front position sensor holds a lower temperature compared to other sensors and ends with the constant temperature. The center position sensor measures temperature increasing significantly and reaches its constant value. Lower back position sensor measures a low temperature at the beginning and ends with a constant temperature. Back left and back right position sensors measures almost the same value of relative humidity and ends with a constant value of temperature. Center right position sensor measures lower values at the beginning of the experiment and ends with a higher value of temperature compare with other positions of sensors.

Moreover, the front and ambient position sensor in the relative humidity graph from figure 4.25 almost the same records lower relative humidity at the beginning of the experiment and continues with a constant value to the end of the experiment. The back left position sensor measures high relative humidity at the beginning of the graph and ends with constant high temperature at the end of the experiment. The lower back position sensor begins with quite high relative humidity value and it does end with constant value at the end of the experiment. Center position sensor records lower value from the beginning of the experiment and ends with a constant value at the end of the experiment. The center right and back right position sensor measures lower value at the beginning and it continues with a constant value throughout the experiment. The ambient position sensor records continue the constant value of relative humidity throughout the experiment.

4.3.2 Overall comparison graph for each type at center position

<u>Type A helmet</u>

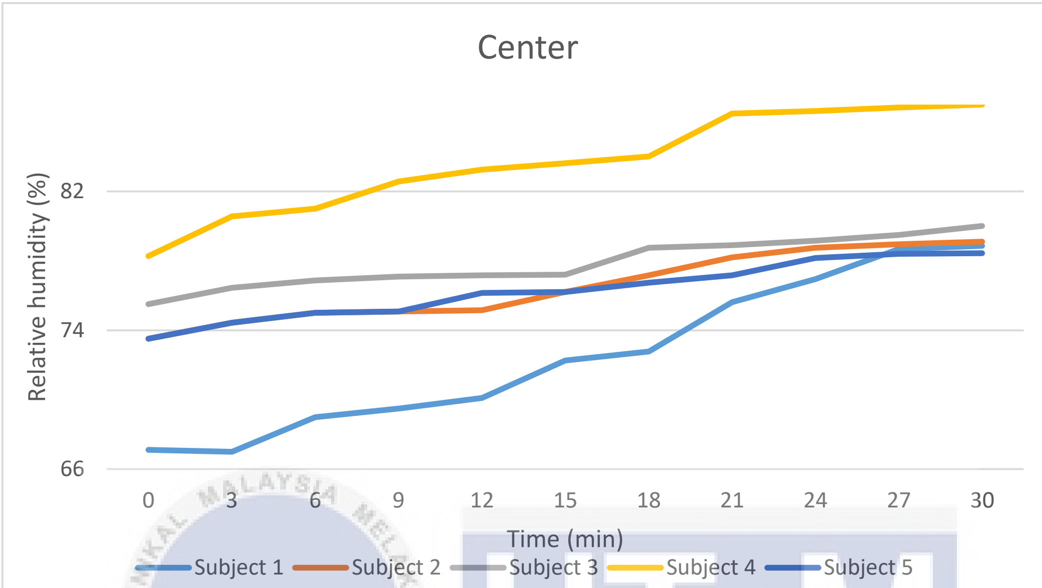


Figure 4.26 Overall temperature graph for type A helmet at center position

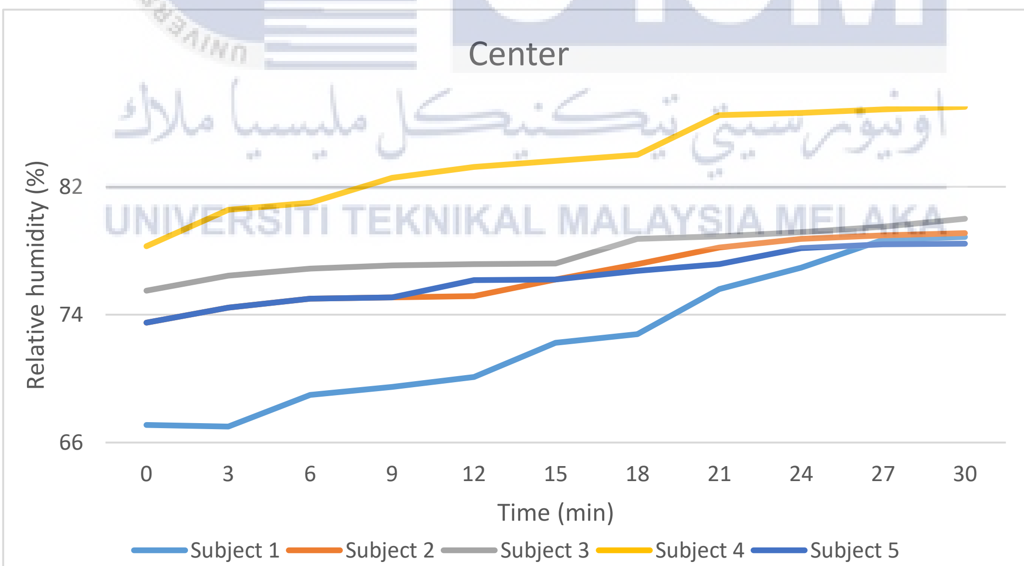


Figure 4.27 Overall relative humidity graph for type A helmet at center position

Type B helmet

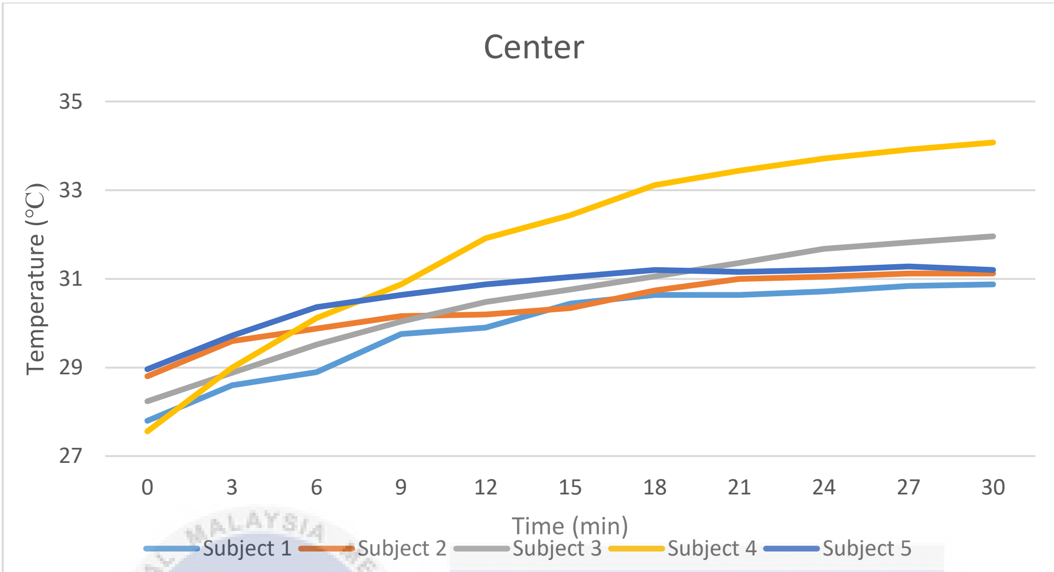


Figure 4.28 Overall temperature graph for type B helmet at center position

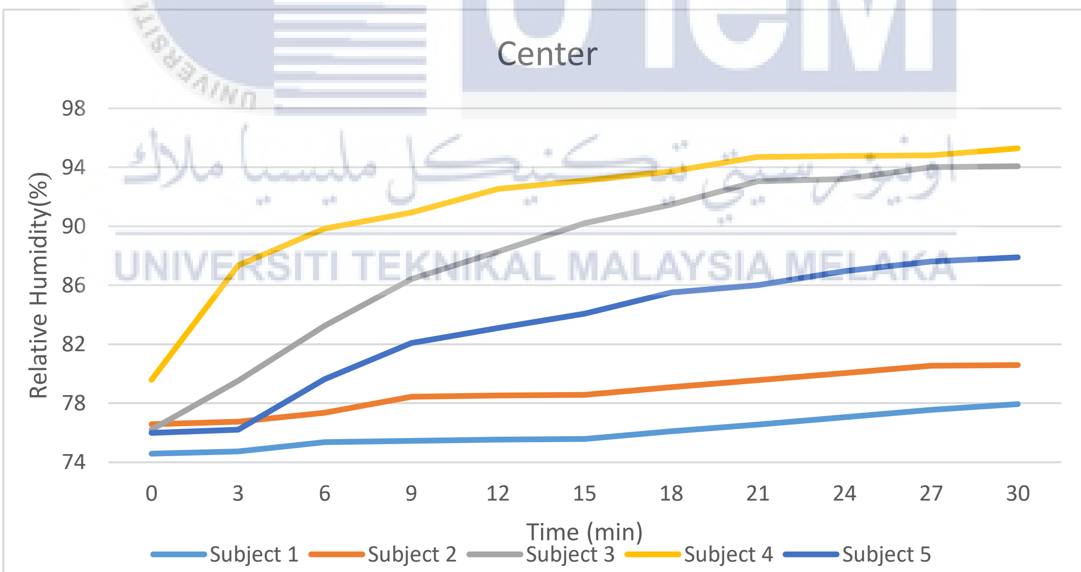


Figure 4.29 Overall relative humidity graph for type B helmet at center position

Type C helmet

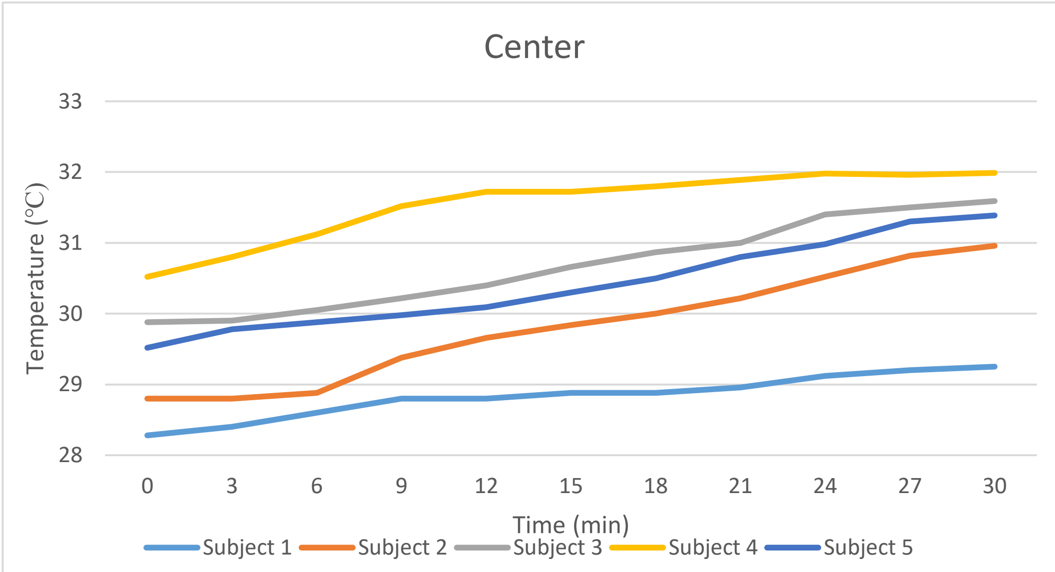


Figure 4.30 Overall temperature graph for type C helmet at center position

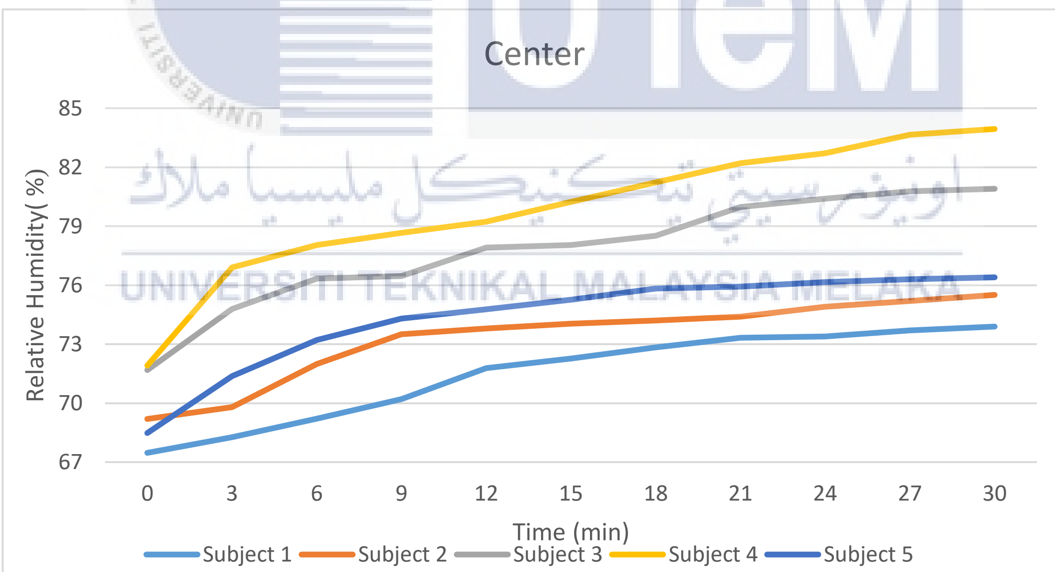


Figure 4.31 Overall relative humidity graph for type C helmet at center position

The graphs from figure 4.26 – 4 .31 shows the overall comparison for the all subjects for the center position. The graph of subject 5(joeshua) shows high in temperature and relative humidity level and subject 1 (saras) shows lower in temperature and relative humidity level for all the types of helmet which is type A, type B and type C. This cause of the head size of the each of the human subject. Subject 5 has bigger size compare other subjects and subject 1 has lower size compare with other subjects. The subject 5 has higher temperature and relative humidity level because it cause of the head is too fit and tight for the helmet which stops the air flow go through inside the helmet and subject 1 has lower temperature and relative humidity level because there is gaps between the helmets and the head. This cause of the head size of the subject is smaller compare to subject 5. The other subjects have average head size compare with subject 1 and subject 5 which cause their temperature and relative humidity level maintain in between of them. So, for this issue head size is a important matter in this experiment which cause the changes in the temperature and relative humidity level. The other sensor position also will have the same pattern as this center position because the changes in the head size.

4.3.3 Overall human perception survey for each type

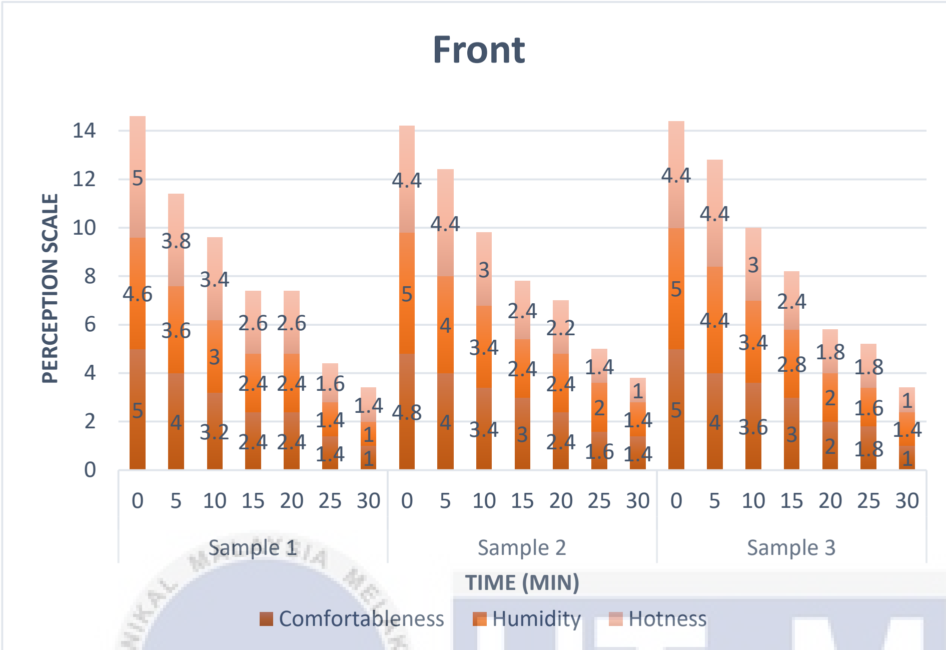


Figure 4.32 Overall human perception scale for front position sensor

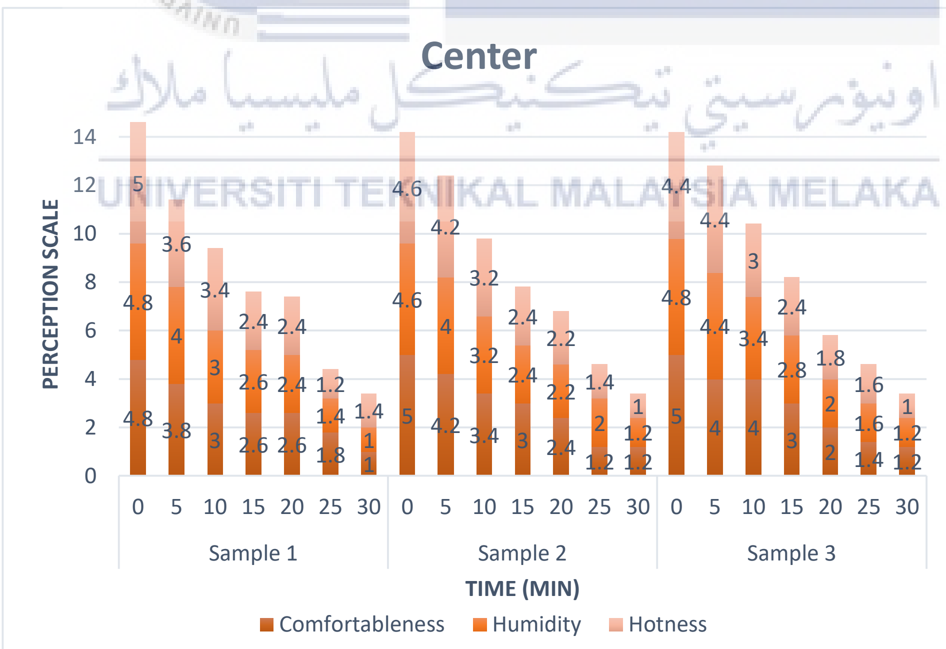


Figure 4.33 Overall human perception scale for center position sensor

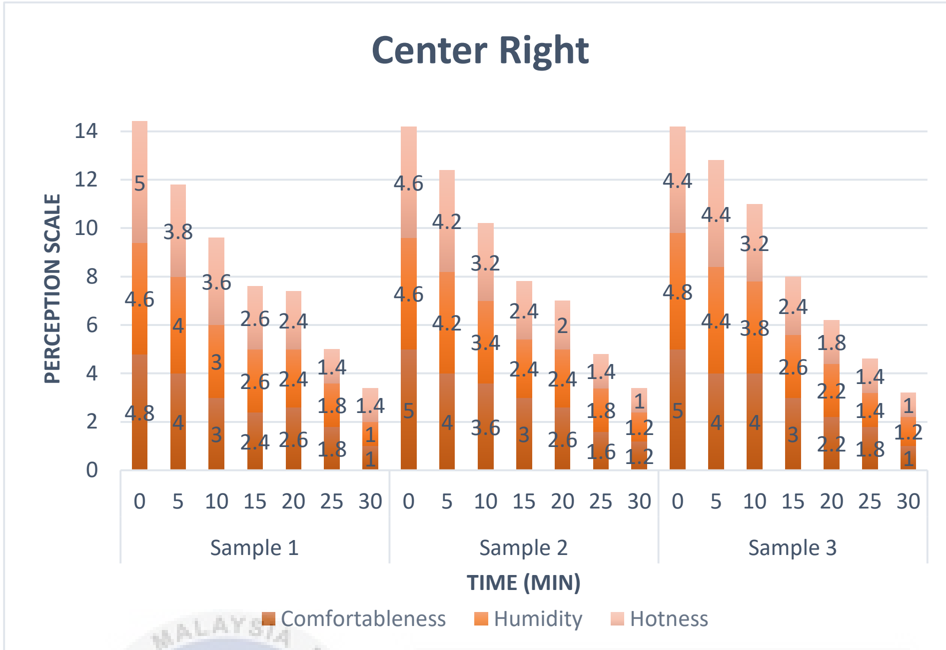


Figure 4.34 Overall human perception scale for center left position sensor

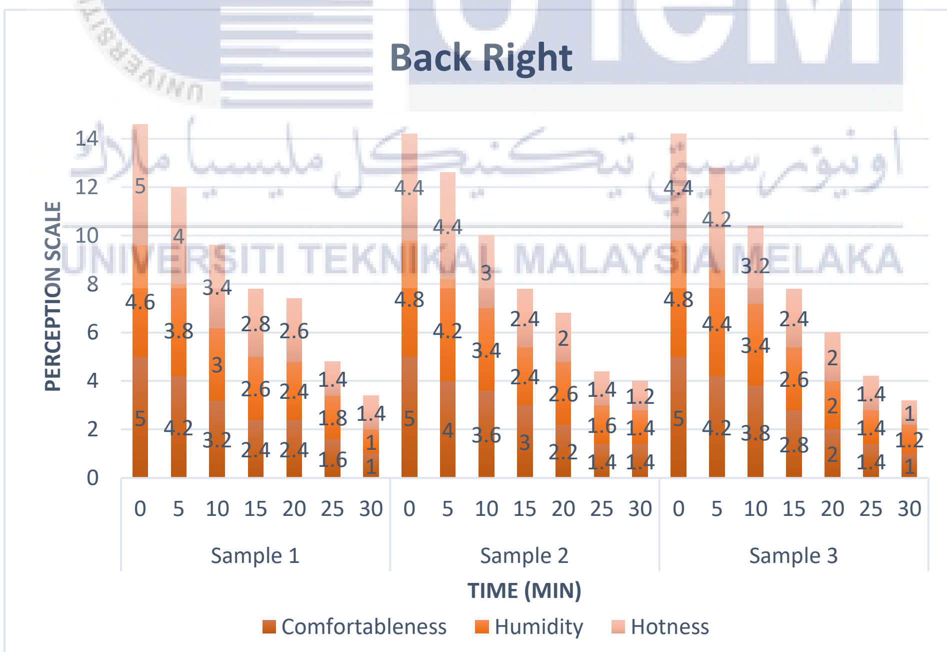


Figure 4.35 Overall human perception scale for back right position sensor

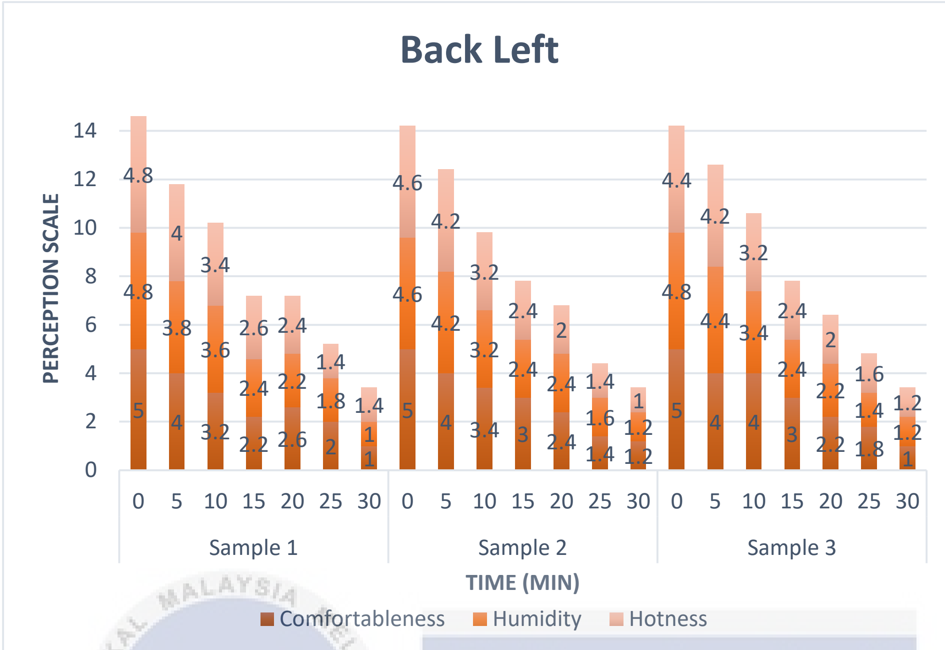


Figure 4.36 Overall human perception scale for back left position sensor

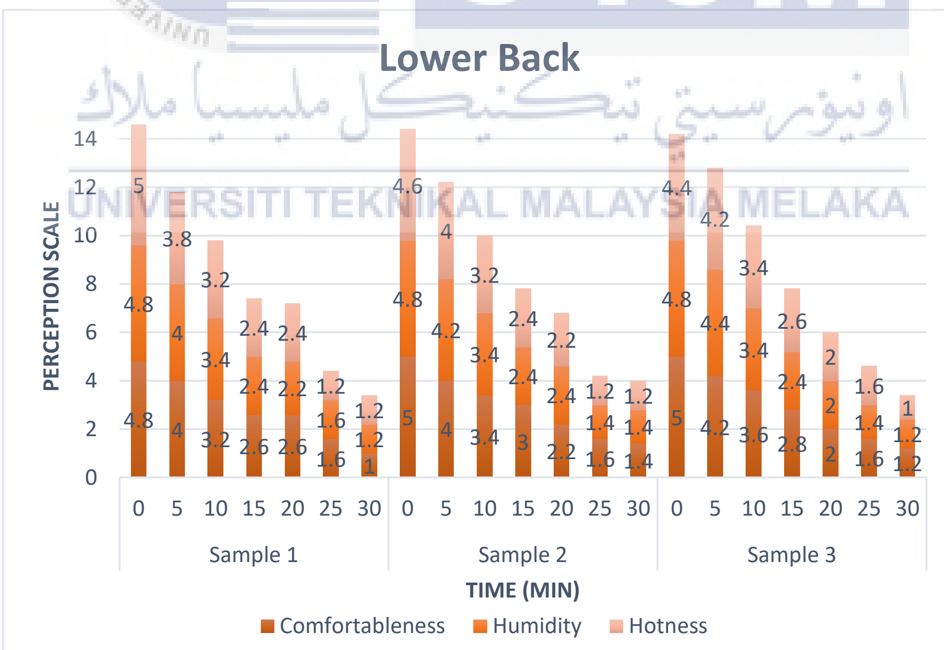


Figure 4.37 Overall human perception scale for lower back position sensor

The human perception survey form is given to all the subjects who undergo the testing and the subjects need to rate how they feel on the head throughout the experiment. The duration of the experiment was 30 minutes and the subjects need to rate for certain minutes based on how they felt throughout the experiment. The survey was done for all the types of the helmet which is type A, full face helmet, type B which is open face helmet and type C which is half face helmet.

Based on figure 4.26-4.31, most of the subjects rated the most uncomfortableness, most humid and very hot at the end of the experiment. At the beginning of the experiment, the subjects felt very comfortable, very dry and very cold based on the rating from the subjects. The front position of the head is rated the most uncomfortableness, most humid and very hot at the end of the experiment and the graph decreasing slowly depends on the rating from subjects based on how they felt. Type A and type C helmet rated very uncomfortableness, very humid and very hot based on the rating and the type B helmet is much better rating compare to another two helmets.

Besides that, the back right position and back left position holds almost the same rating for most uncomfortableness, very humid and very hot for the three types of helmet which is type A, type B and type C based on the subjects rating throughout the experiment and the rating decrease significantly throughout the experiment for the 30 minutes. The center and center-right position rated almost the same for the most uncomfortableness, very humid and very hot based on the subjects rating throughout the experiment and the graph decrease considerably for the time period for all the types of helmet. Furthermore, front and lower back position rating is almost the same for most uncomfortableness, very humid and very hot based on the subjects felt throughout the experiment for 30 minutes for all types of the helmet.

4.3.3.1 Overall comparison human perception survey for each type

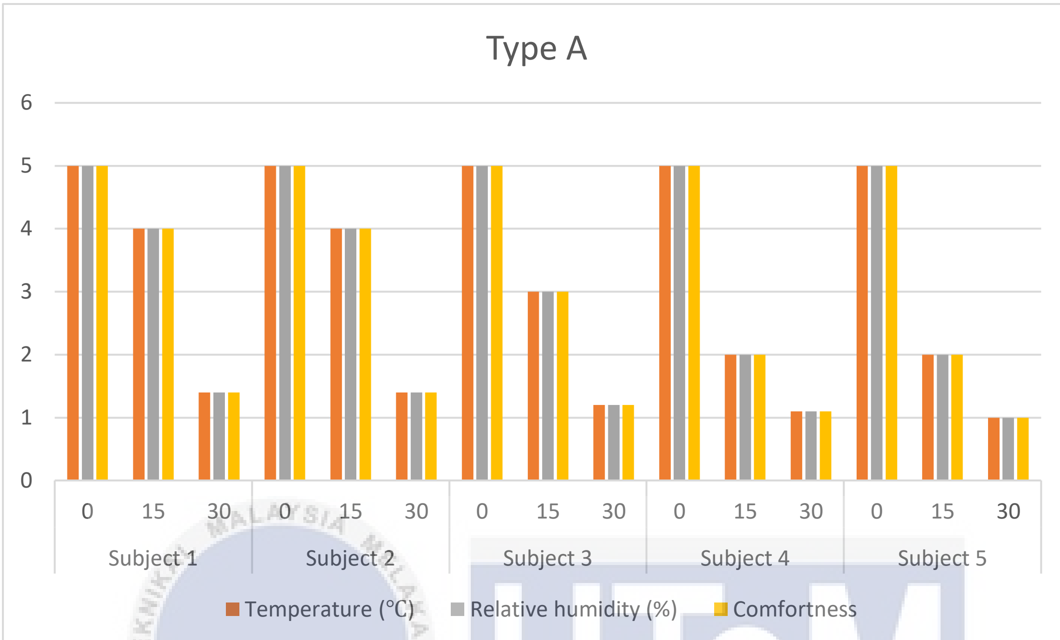


Figure 4.38 Overall human perception scale for type A helmet

	1	2	3	4	5
A	Most uncomfortable	Little uncomfortable	Moderate	Little comfortable	Most comfortable
B	Most humid	Little humid	Moderate	Little dry	Most dry
C	Very hot	Hot	Moderate	Cold	Very cold

This is the overall human perception for full face helmet that classify by each of the human subject and we can see there is difference in the pattern of the bar chart by changing the difference in the size of the head. This is because subject 5(Joeshua) had a bigger circumference size of his head compare with subject 1(saras). Therefore, the helmet is too fit for subject 5 which does not allow the air to enter in of the helmet compare with other subjects which makes the inner of helmet produce high level heat and humidity. There is also no ventilation holes on the helmet which can let the air to enter in to cool down the inner side of the helmet.

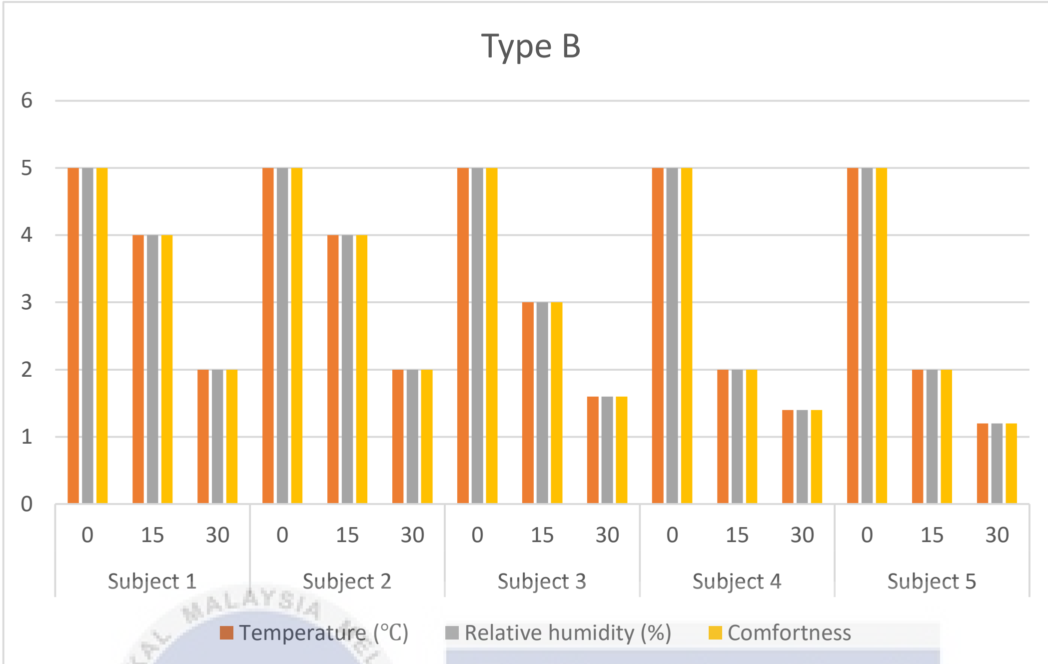


Figure 4.39 Overall human perception scale for type B helmet

This is the overall human perception for open face helmet that classify by each of the human subject and we can see there is difference in the pattern of the bar chart by changing the difference in the size of the head. This is because subject 5(Joeshua) had a bigger circumference size of his head compare with subject 1(saras). Therefore, the helmet is too fit for subject 5 which does not allow the air to enter in of the helmet compare with other subjects which makes the inner of helmet produce high level heat and humidity. The air can enter easily to this inner side of the helmet because this is open face helmet which can easily cool down the inner side of the helmet and there is also no ventilation holes on the helmet as well. This helmet has the best human perception scale compare with another two helmets.

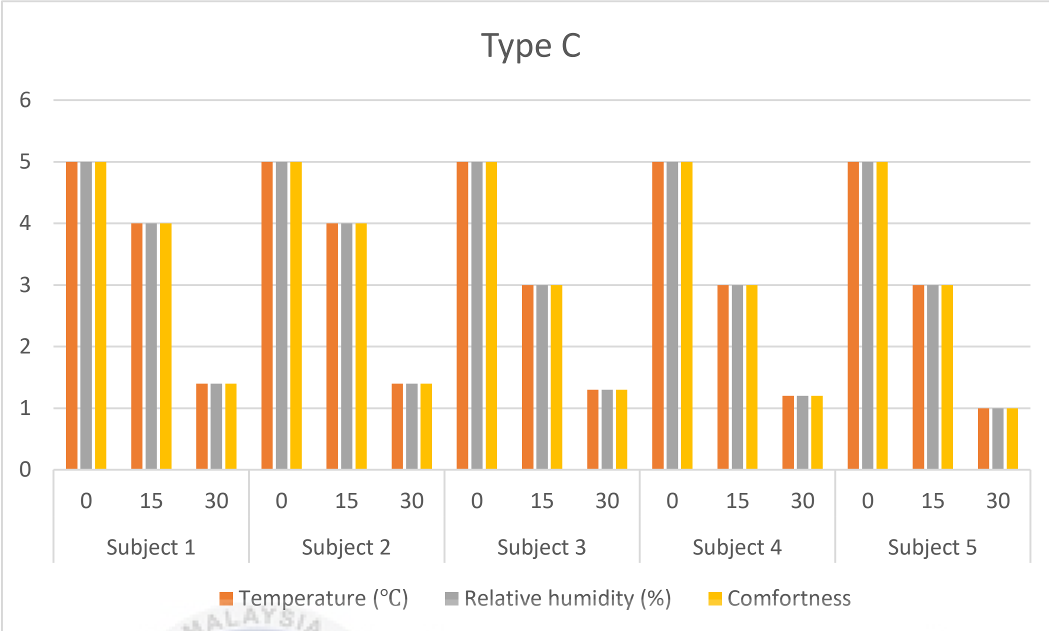


Figure 4.40 Overall human perception scale for type C helmet

This is the overall human perception for half face helmet that classify by each of the human subject and we can see there is difference in the pattern of the bar chart by changing the difference in the size of the head. This is because subject 5(Joeshua) had a bigger circumference size of his head compare with subject 1(saras). Therefore, the helmet is too fit for subject 5 which does not allow the air to enter in of the helmet compare with other subjects which makes the inner of helmet produce high level heat and humidity. This helmet is covered by the cloth surround the helmet which stops the air to enter in. This made the increase in temperature and humidity level.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In a nutshell, human thermal comfort is a combination of how we feel which is subjective sensation and objective interaction with the environment which is heat and mass transfer rates regulated by the brain. Comfort depends on several physical magnitudes that we can classify as person related and environment related. The purpose of a thermal comfort analysis maybe isis set as finding an appropriate function of the physical parameters such as background radiant temperature, air temperature, air humidity, wind speed, clothing, metabolic rate and core temperature which would yield the corresponding comfort or discomfort level in the seven degrees of comfort. It is expected the system will be able to create a significant temperature and heat transfer reduction when compared with a different body temperature of human the thermal discomfort of a motorcycle helmet user is being developed and the heat transfer from a subject's head and body will be identified and studied based on the temperature of the body. The first objective of the report which is to investigate the effect of different head size and the heat transfer on thermal comfort of the helmet user approach has been achieved as the entire test rig developed and experimented. Furthermore, the second objective of the study which is to determine and analyse the temperature and relative humidity inside different helmets by human testing. The head size which is tested is between 55cm to 60cm and all the size of the three types of helmets that are used is standardized to a large size. Such testing was conducted using five different human subjects.

From type A overall temperature graph (figure 4.20), the center has the lowest temperature value compare to another five sensor position. Besides that, the overall relative humidity graph from figure 4.21 shows the center position has the constant and lower value of relative humidity. This is because this full face helmet had a small ventilation hole on the top side of the helmet. Meanwhile, the overall temperature graph (figure 4.22) from the type B helmet experiment shows the front and center sensor position had the lowest value of temperature followed by the relative humidity graph (figure 4.23) at the same sensor position which is constant and lower value compared to other sensor positions. Thus, exist such values due to the open face and the air can easily pass through and maintain the temperature and the relative humidity level. Moreover, the overall temperature graph (figure 4.24) for type C helmet places lower temperature value at the lower back and front sensor position followed by the overall relative humidity (figure 4.25) value had the lowest and constant value at the same position compared to other sensor positions. This is due the air intake is more at the front and lower back of the helmet because this is a half face helmet. Furthermore, helmet type B which is open face helmet is more better compare to other two helmets because it easy for the air to go through in the helmet through open face and its easy to maintain the temperature and relative humidity level inside the helmet. This helmet is safety to wear and as well as its comfortable and ease for daily usage. The effect of using different types of helmet identified by the temperature and relative humidity changes when the experiment being carried out and also different head size plays vital role in increase or decrease in temperature and relative humidity. Moreover, a deeper knowledge of the mechanism of the helmet is very vital in understanding how it actually works to protect the head from injuries. Safety-conscious riders wear helmets as a sensible and responsible choice every time they ride. The wide scope on clean and renewable energy based human comfort related technologies must be further explored in order to reduce the harm caused towards the human and environment.

5.2 Recommendations

Completion of this study resulted in various potential areas for development. First, the type of materials used inside the helmet. Current studies utilize expanded polystyrene (EPS) or its called as styrofoam is one of the most popular materials used for the inner lining in a helmet. It is also commonly known as thermocol and has always been reliable considering its impact-absorbing qualities. The styrofoam is cheap but it does has a certain disadvantage. The riders experiencing more heat produce from the material. Thus, improvisation can be made by selecting suitable phase change material (PCM) which is Glauber Salt that confines inside an aluminium foil. This is to absorb the heat produced inside the helmet and the continuous cooling will achieve until the entire PCM fuses.

Besides that, ventilation holes or breathable vents to accommodate warm weather riders is another improvisation can be created in front or middle or rear side of all the types of helmets. This allows the fresh air circulation flows inside the helmet so that the heat produced in the helmet will quickly remove out and the riders will feel better. Nevertheless, the head size of the subjects plays an important role in producing heat which needs to be taken into consideration which can overcome by wearing a suitable size of the helmet which can fit them well. Meanwhile, the outer material is also an important improvisation that can be made on a helmet. Carbon fiber or composite fibre material is lightweight material that is durable which suits best for creating the outermost layer compare to polycarbonate material which is heavy. This layer will protect the rider's head from the intake of direct sunlight and also reduce the impact on the head. It is also easy for the riders for mobility of the helmet when they felt warm.

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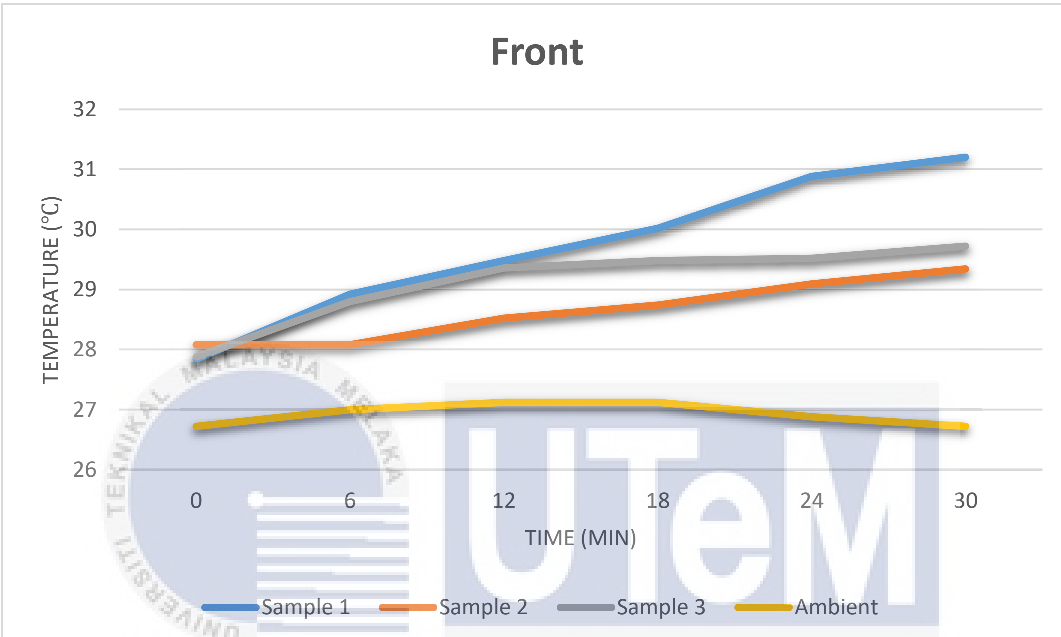
APPENDICES

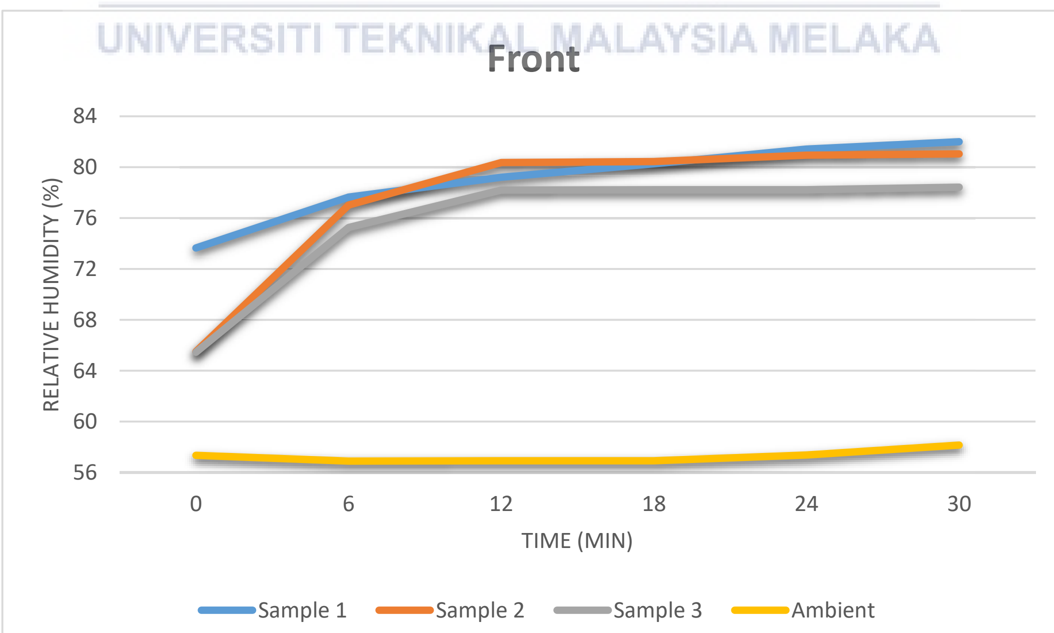
Results for subject 2

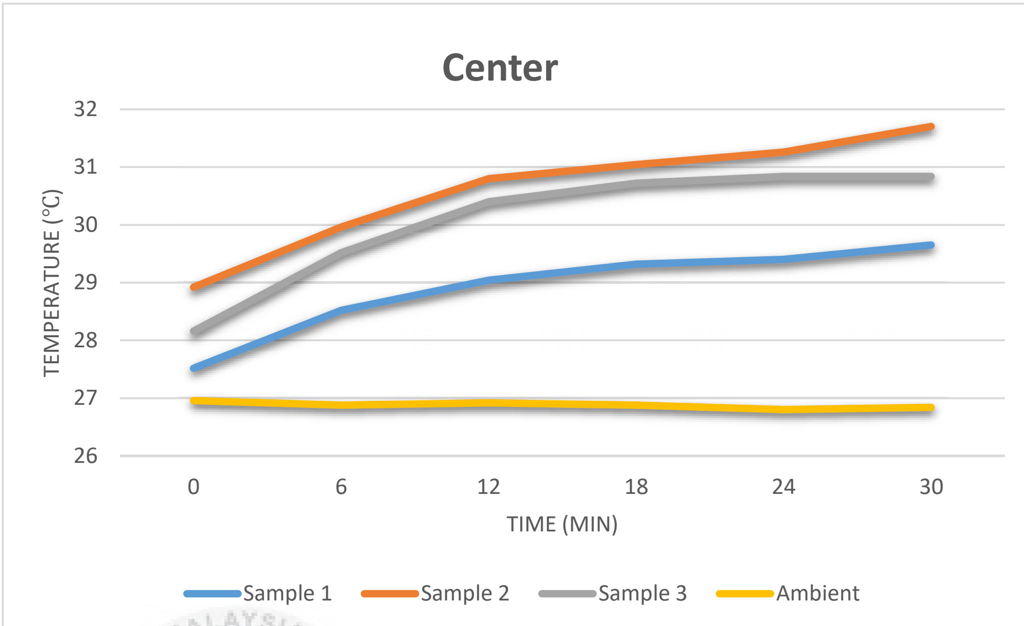
Helmet temperature and relative humidity graphs

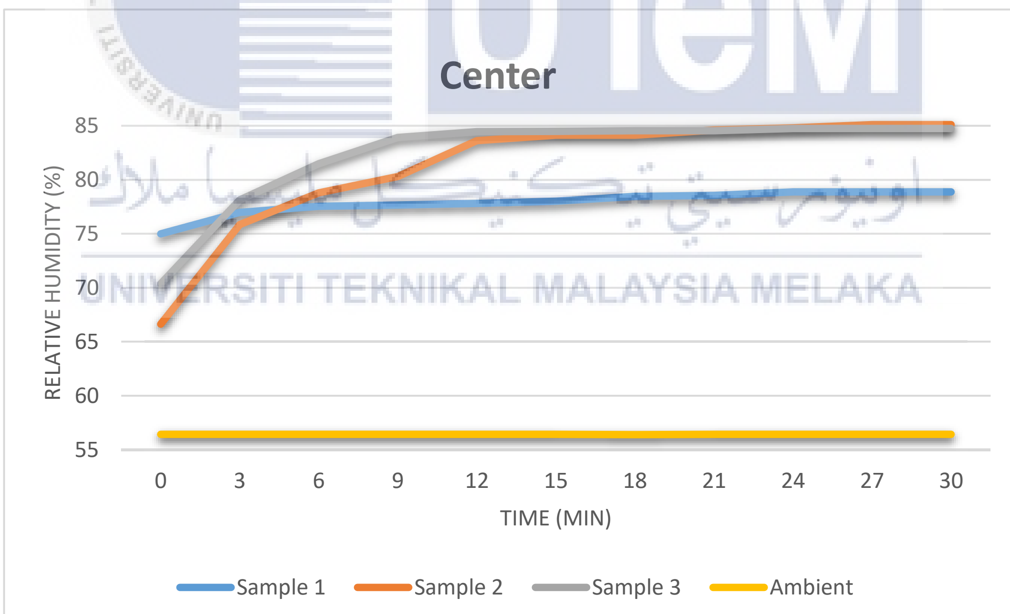
Temperature vs time graph

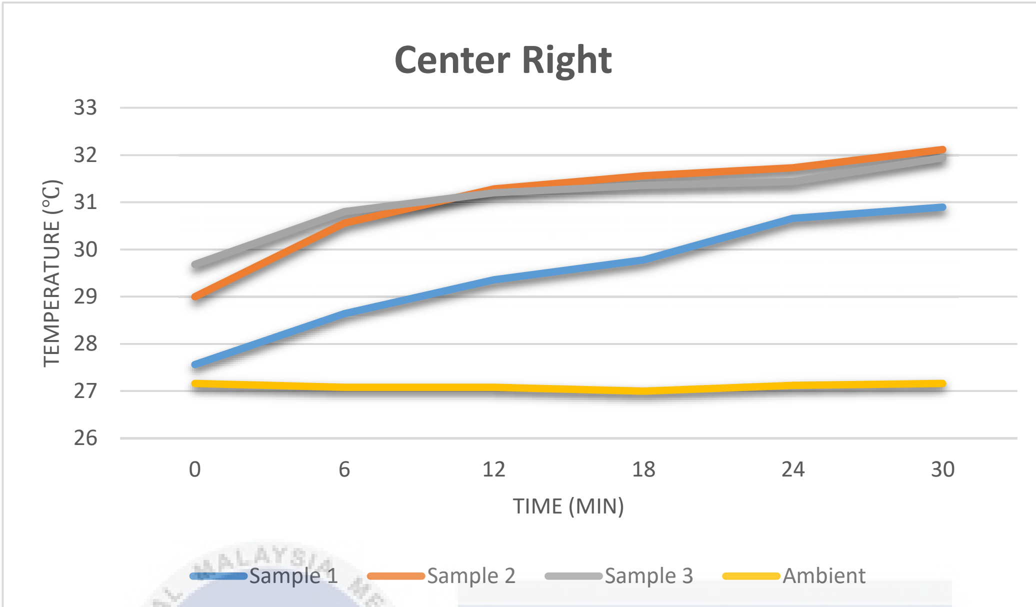


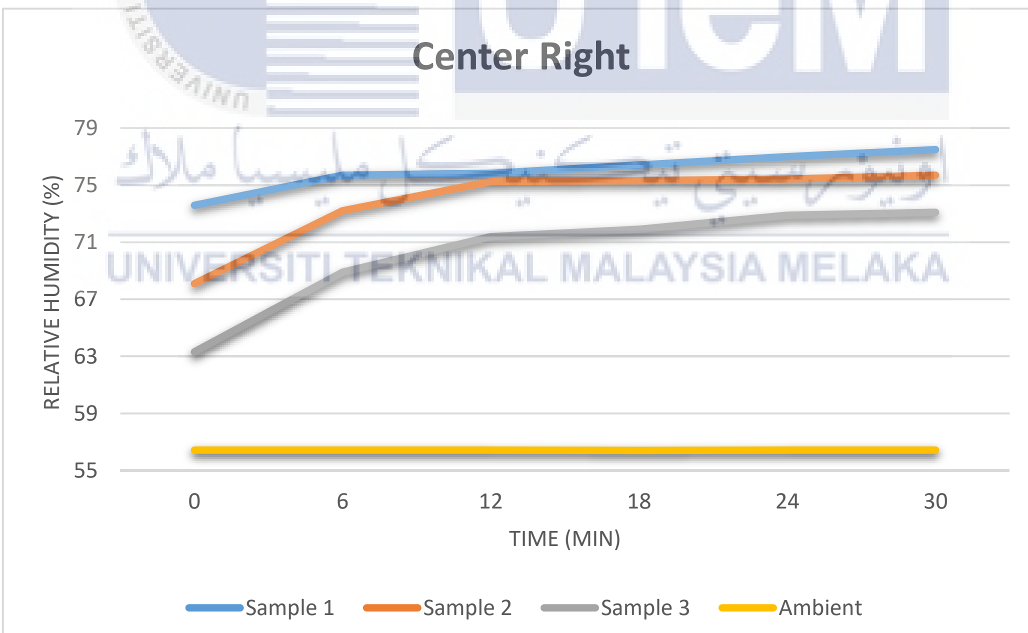
Relative Humidity vs time graph

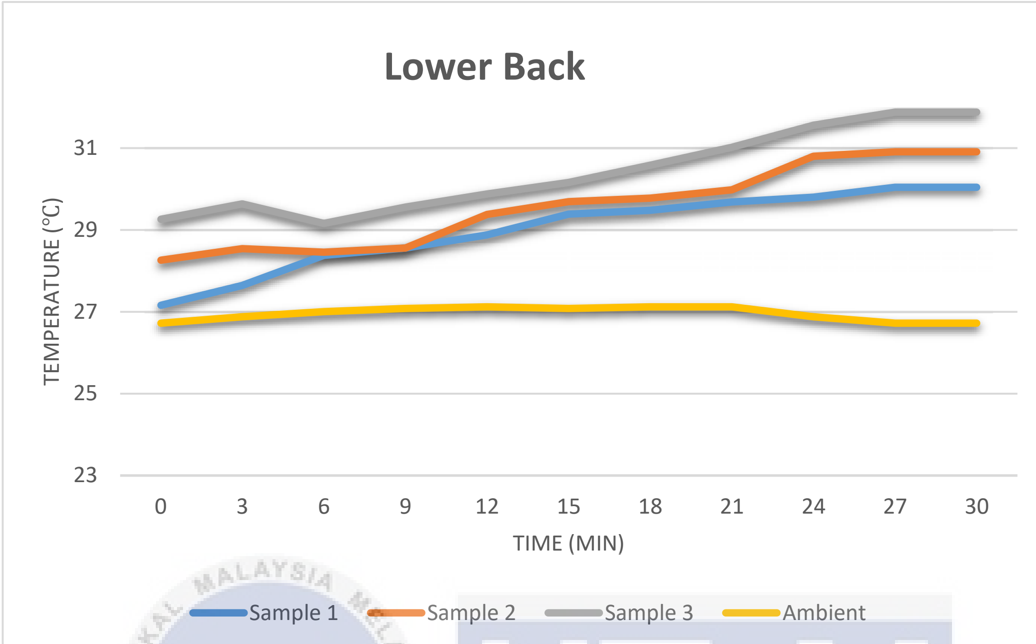


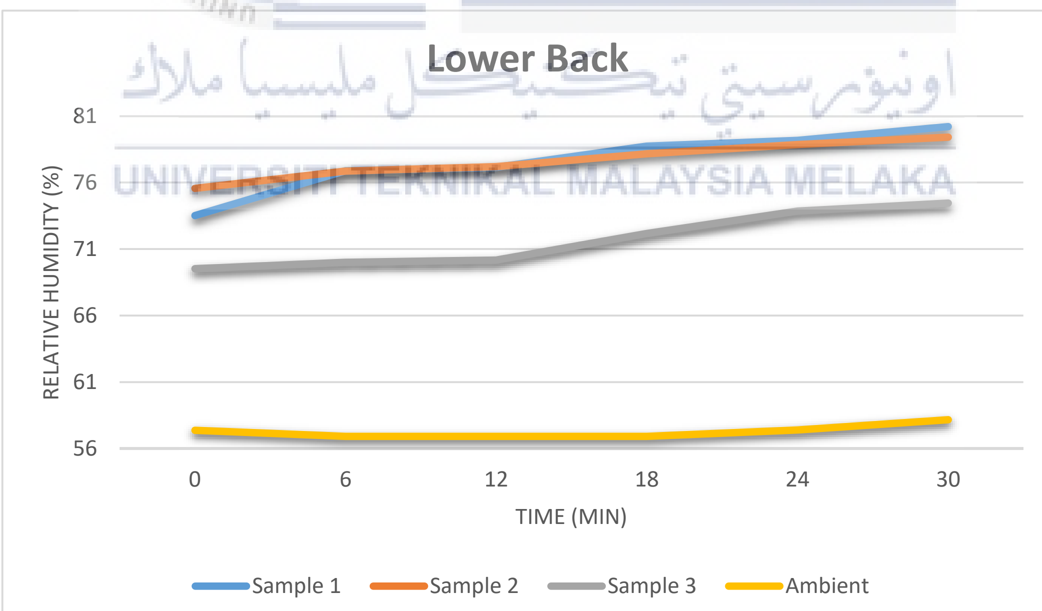

Center
TEMPERATURE (°C)
32
31
30
29
28
27
26
0
6
12
18
24
30
TIME (MIN)
Sample 1
Sample 2
Sample 3
Ambient

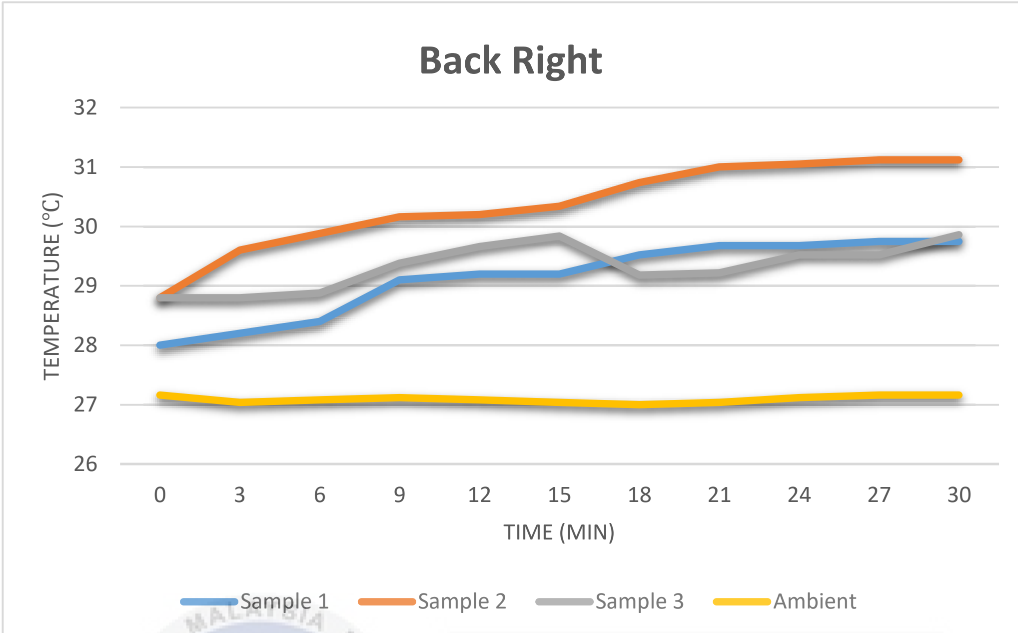

Center
RELATIVE HUMIDITY (%)
85
80
75
70
65
60
55
0
3
6
9
12
15
18
21
24
27
30
TIME (MIN)
Sample 1
Sample 2
Sample 3
Ambient

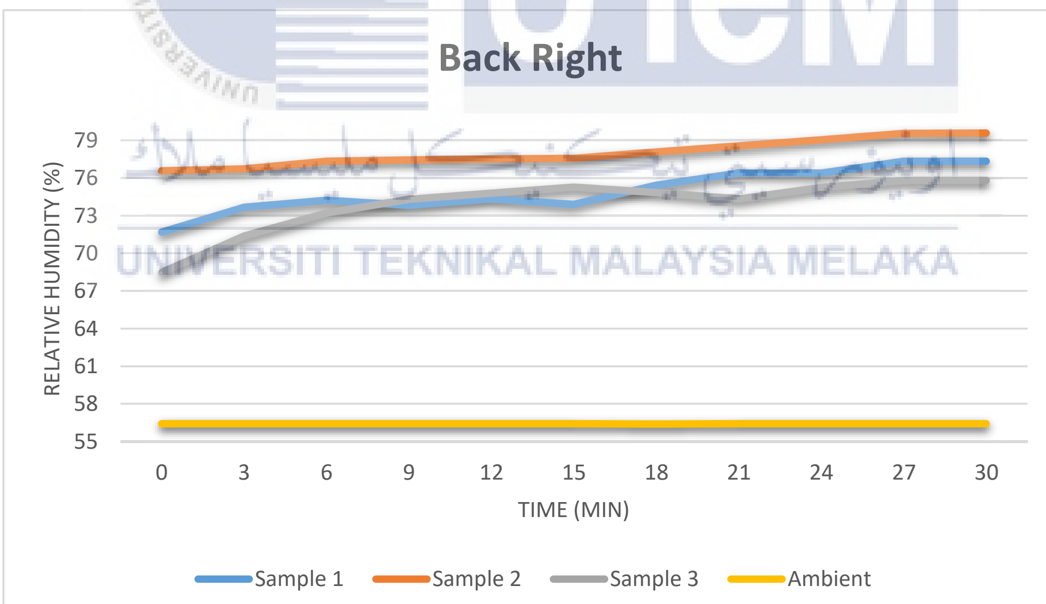

Center Right
33
32
31
30
29
28
27
26
TEMPERATURE (°C)
0
6
12
18
24
30
TIME (MIN)
Sample 1
Sample 2
Sample 3
Ambient

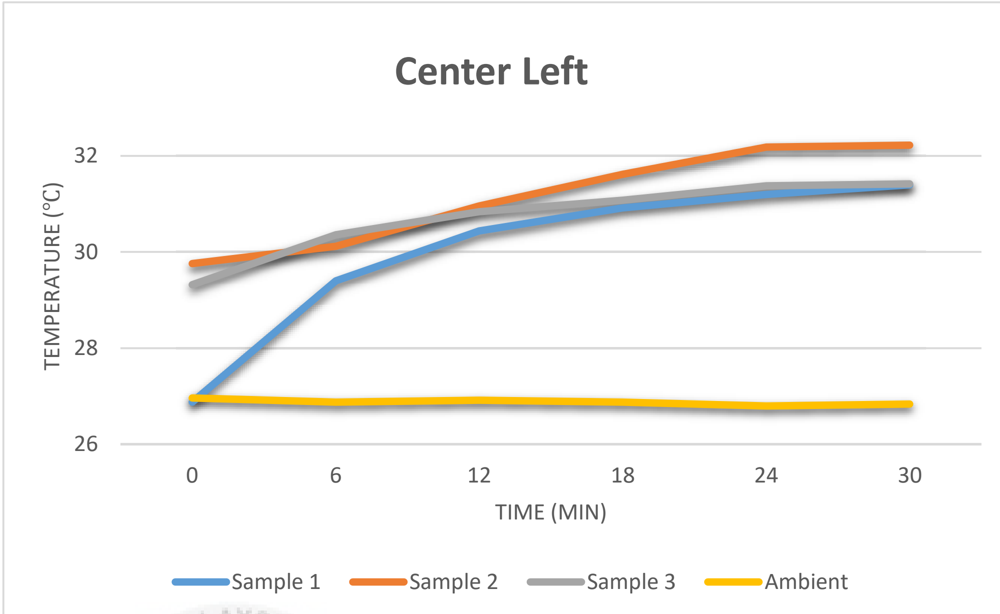

Center Right
79
75
71
67
63
59
55
RELATIVE HUMIDITY (%)
0
6
12
18
24
30
TIME (MIN)
Sample 1
Sample 2
Sample 3
Ambient


Lower Back
TEMPERATURE (°C)
31
29
27
25
23
0
3
6
9
12
15
18
21
24
27
30
TIME (MIN)
Sample 1
Sample 2
Sample 3
Ambient

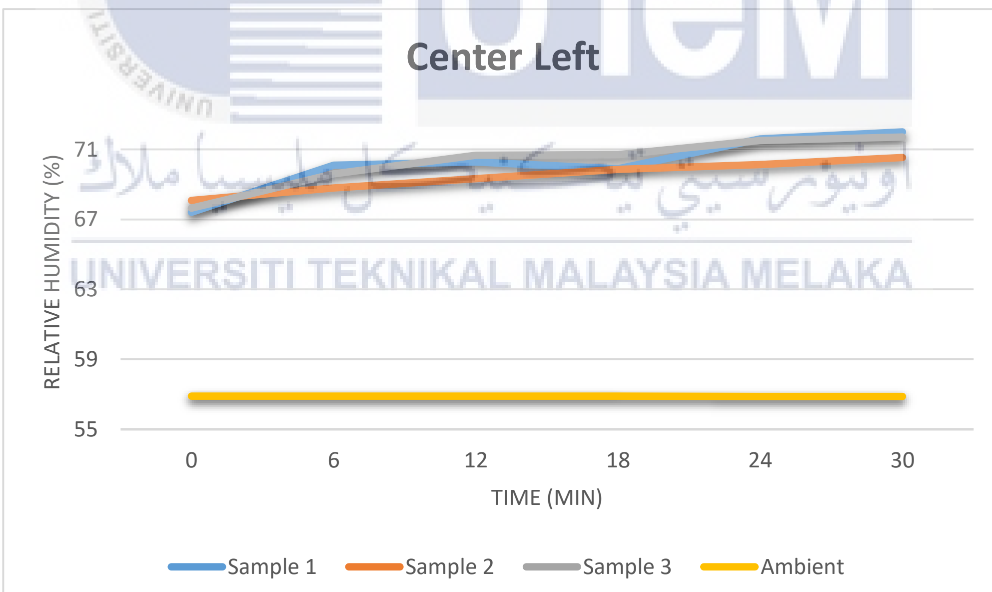

Lower Back
RELATIVE HUMIDITY (%)
81
76
71
66
61
56
0
6
12
18
24
30
TIME (MIN)
Sample 1
Sample 2
Sample 3
Ambient


Back Right
32
31
30
29
28
27
26
TEMPERATURE (°C)
0
3
6
9
12
15
18
21
24
27
30
TIME (MIN)
Sample 1
Sample 2
Sample 3
Ambient


Back Right
79
76
73
70
67
64
61
58
55
RELATIVE HUMIDITY (%)
0
3
6
9
12
15
18
21
24
27
30
TIME (MIN)
Sample 1
Sample 2
Sample 3
Ambient

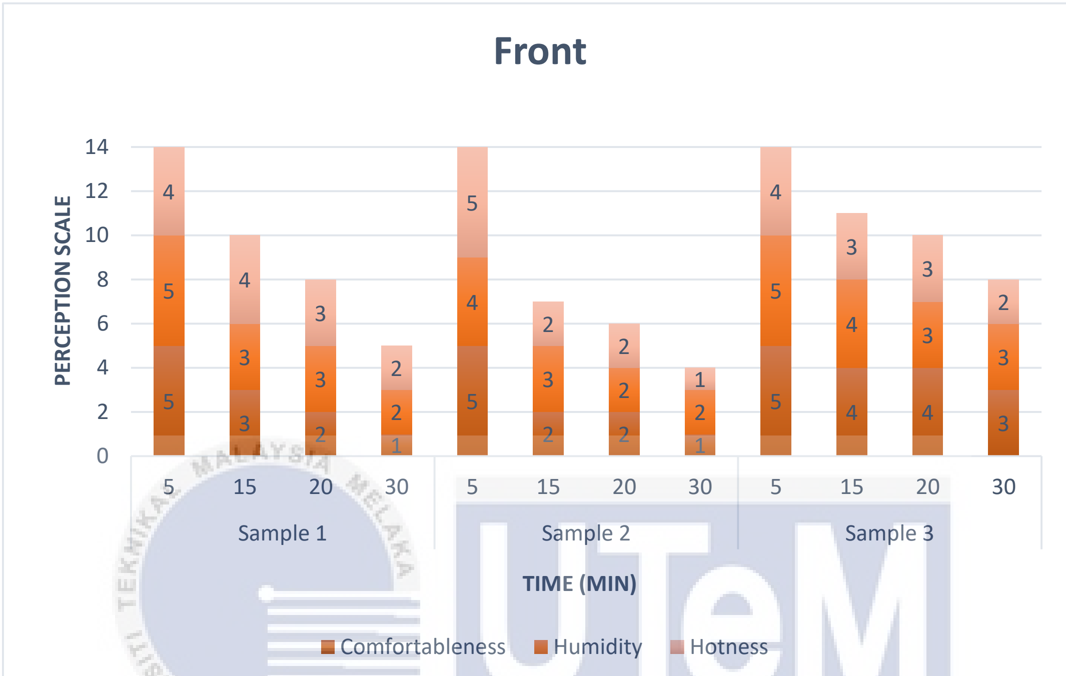


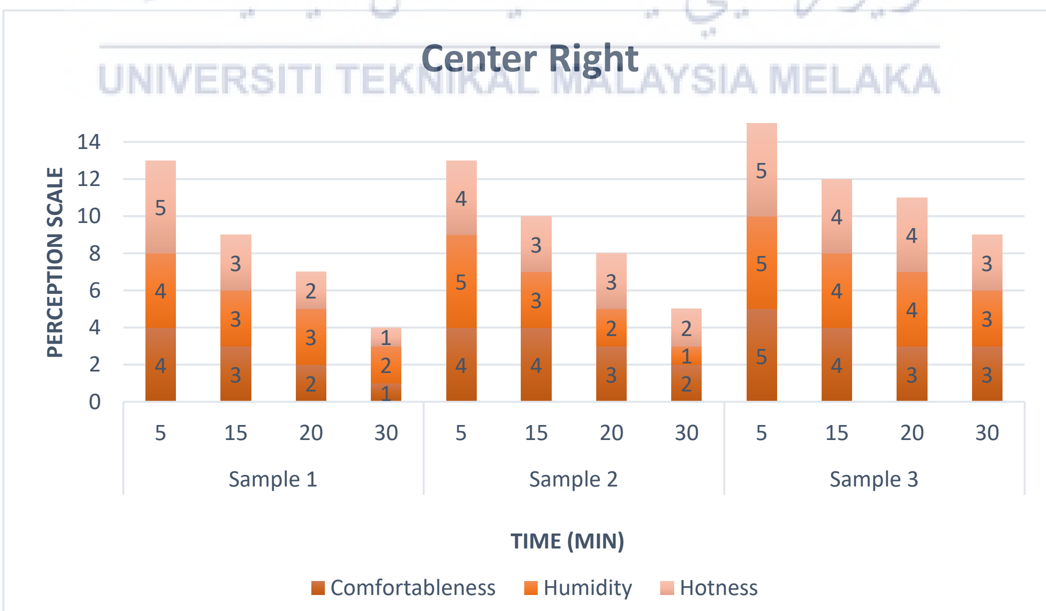
Center Left
TEMPERATURE (°C)
32
30
28
26
0
6
12
18
24
30
TIME (MIN)
Sample 1
Sample 2
Sample 3
Ambient

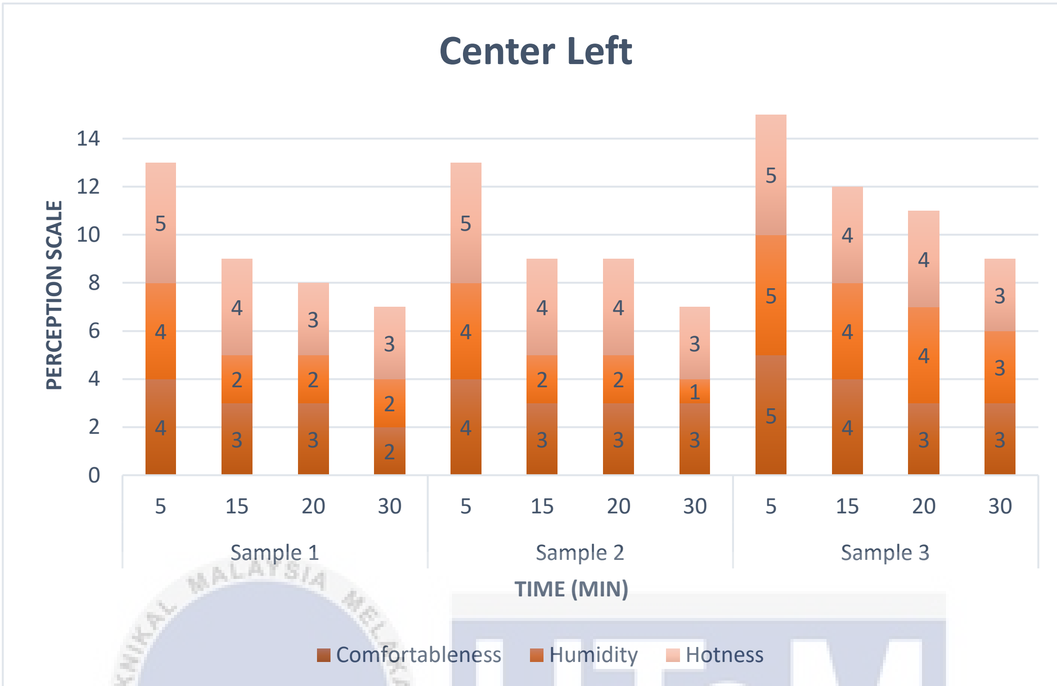


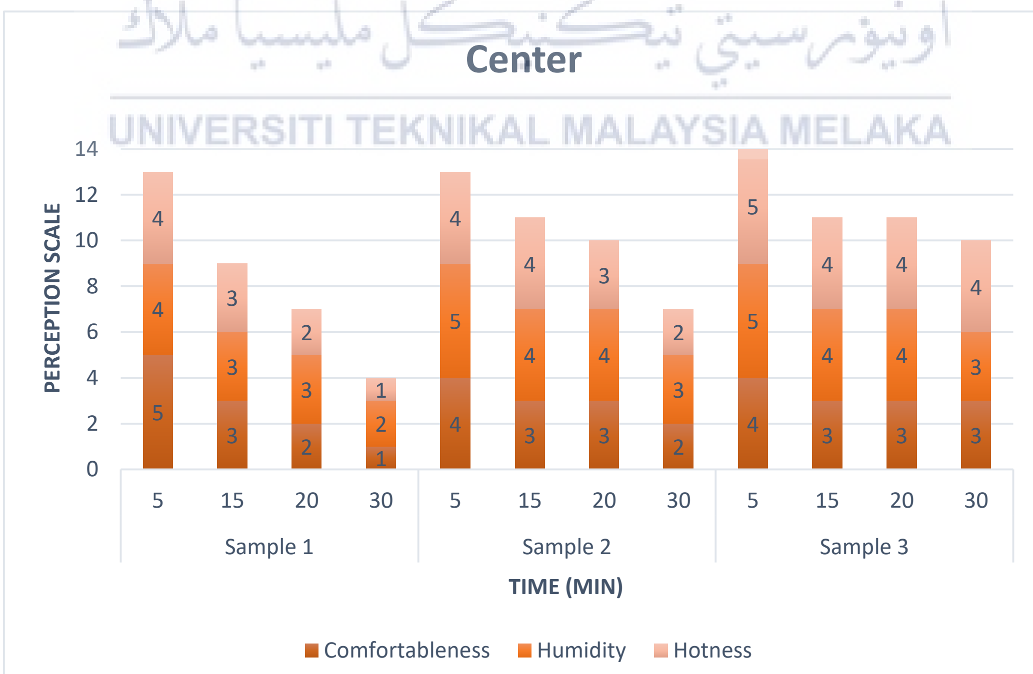
Center Left
RELATIVE HUMIDITY (%)
71
67
63
59
55
0
6
12
18
24
30
TIME (MIN)
Sample 1
Sample 2
Sample 3
Ambient

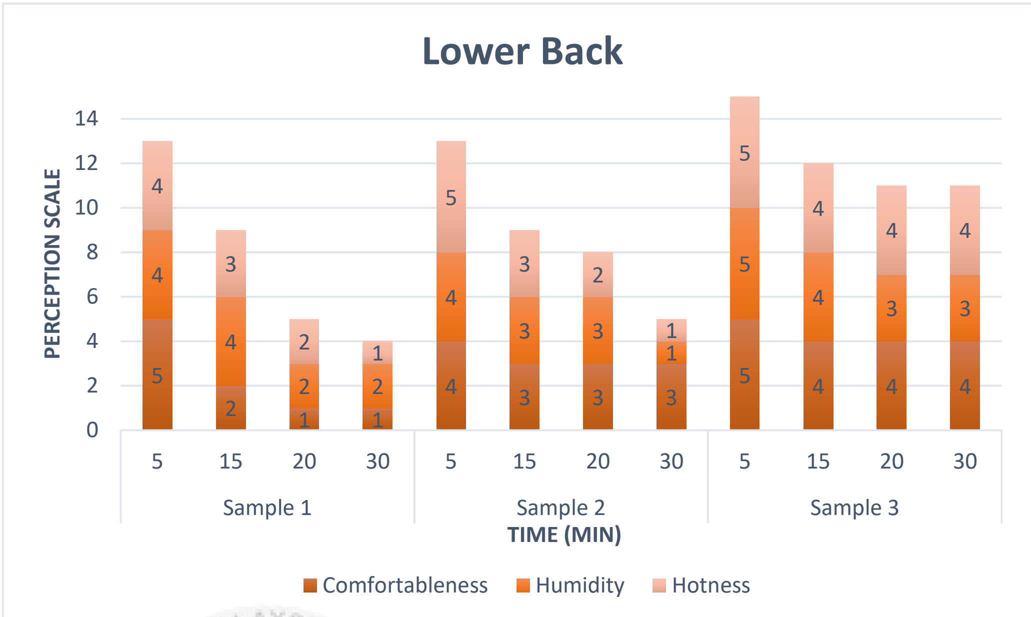
Human perception bar chart for subject 2

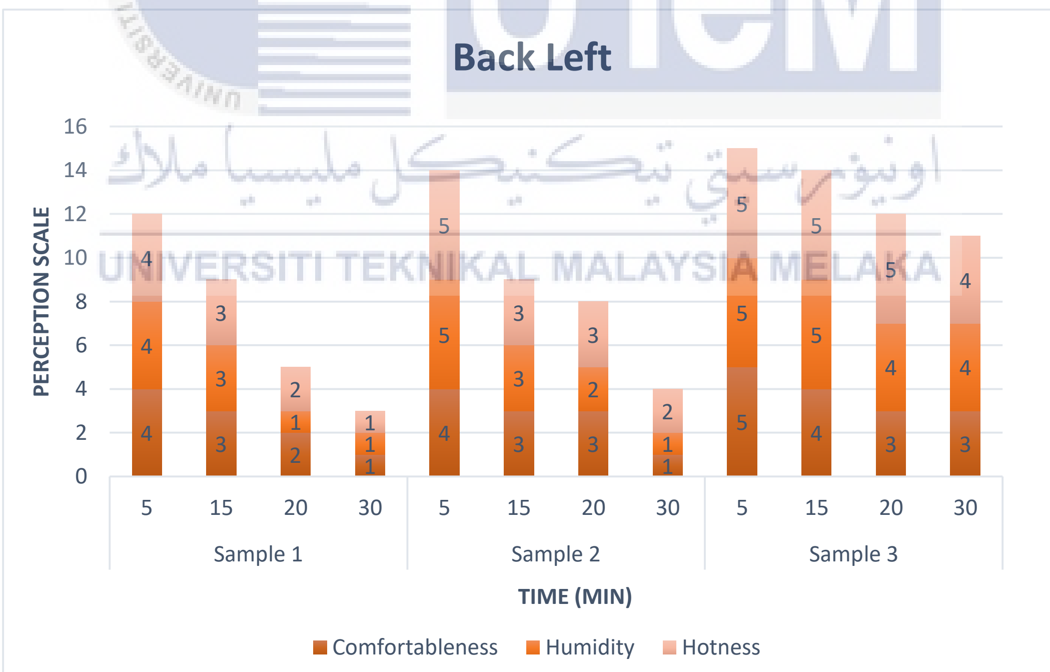





Center Left
PERCEPTION SCALE
14
12
10
8
6
4
2
0
5
15
20
30
Sample 1
Sample 2
Sample 3
TIME (MIN)
Comfortableness
Humidity
Hotness


Center
PERCEPTION SCALE
14
12
10
8
6
4
2
0
5
15
20
30
Sample 1
Sample 2
Sample 3
TIME (MIN)
Comfortableness
Humidity
Hotness

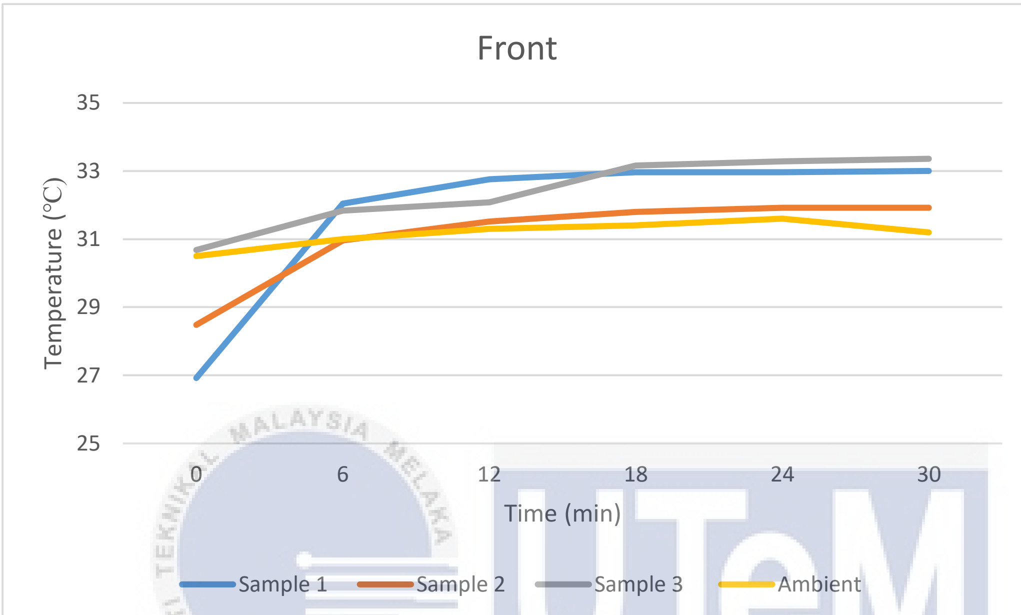

Lower Back
PERCEPTION SCALE
TIME (MIN)
Sample 1
Sample 2
Sample 3
Comfortableness
Humidity
Hotness


Back Left
PERCEPTION SCALE
TIME (MIN)
Sample 1
Sample 2
Sample 3
Comfortableness
Humidity
Hotness

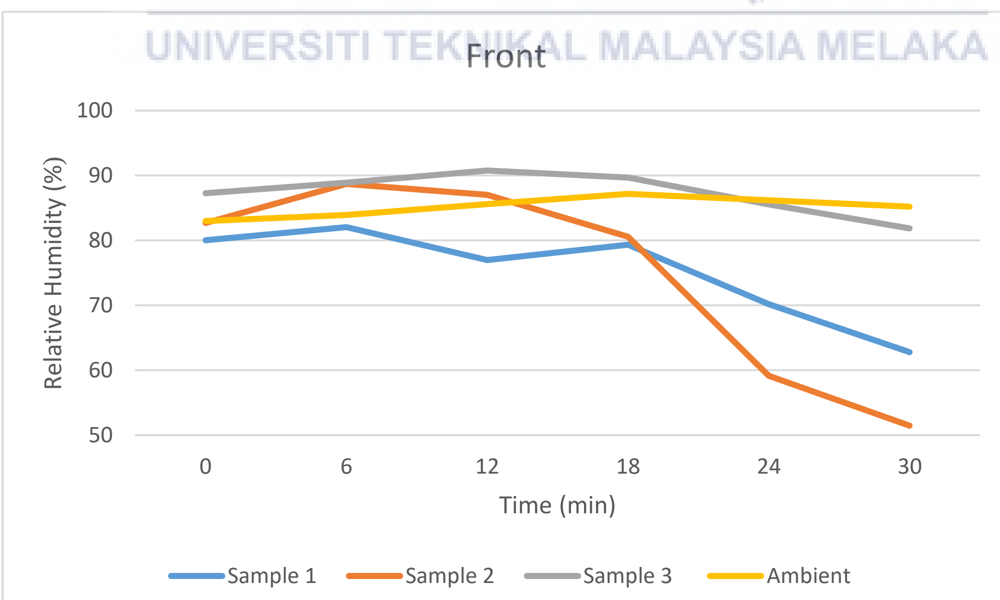
Results for subject 3

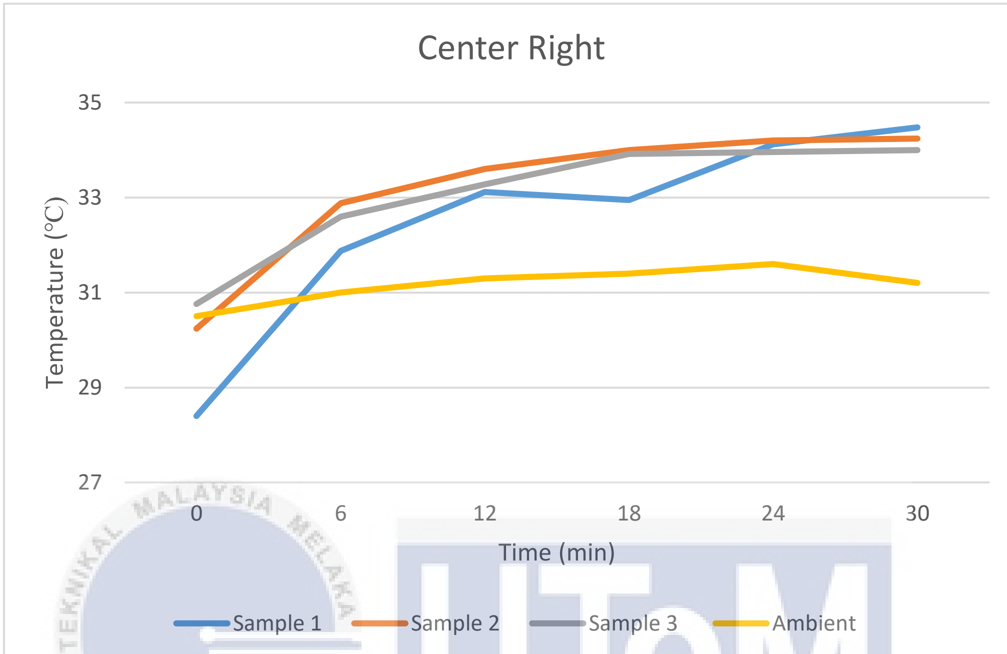
Helmet temperature and relative humidity graphs

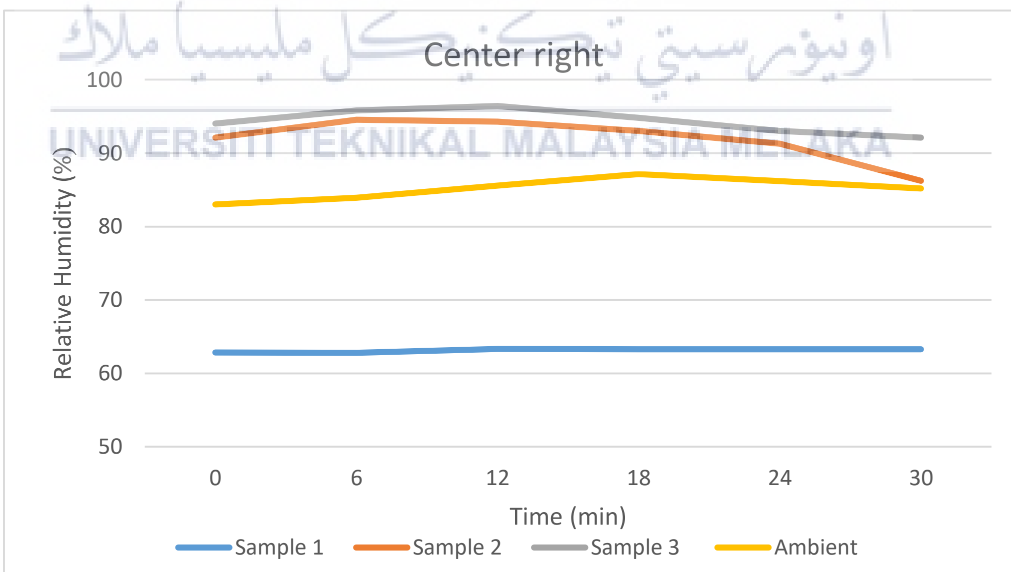
Temperature vs time graph

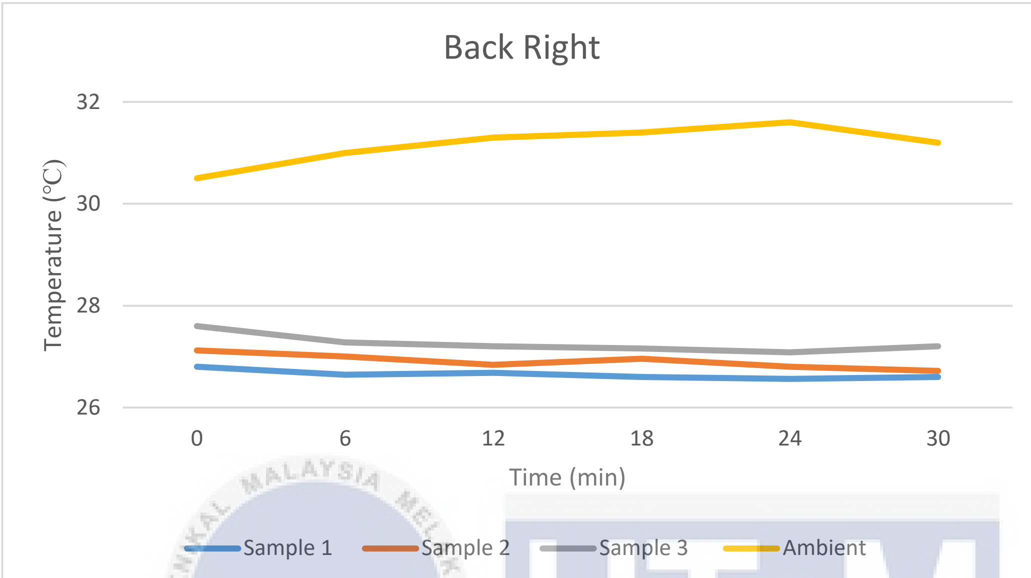


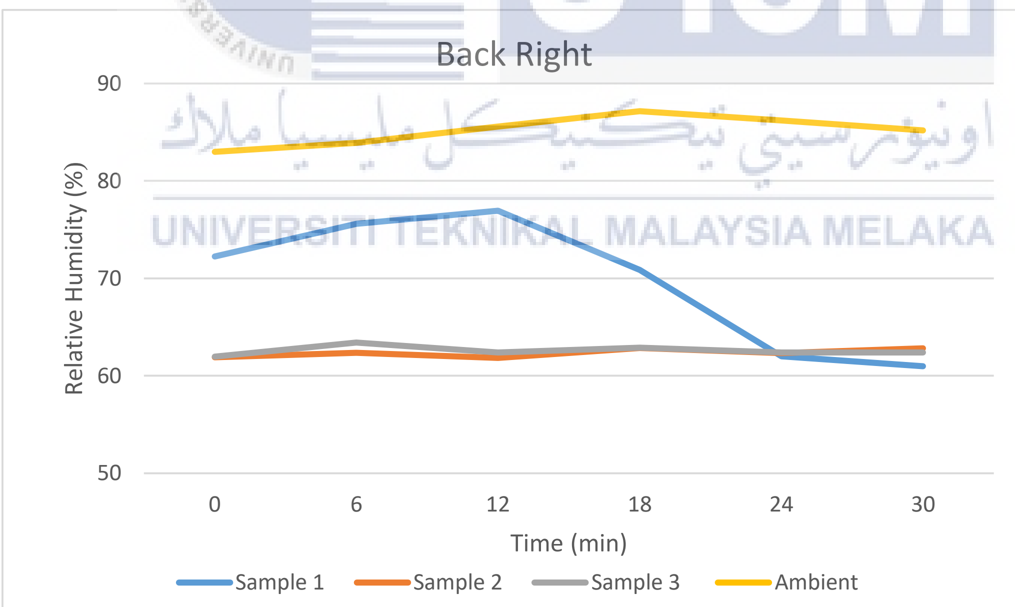
Relative Humidity vs time graph

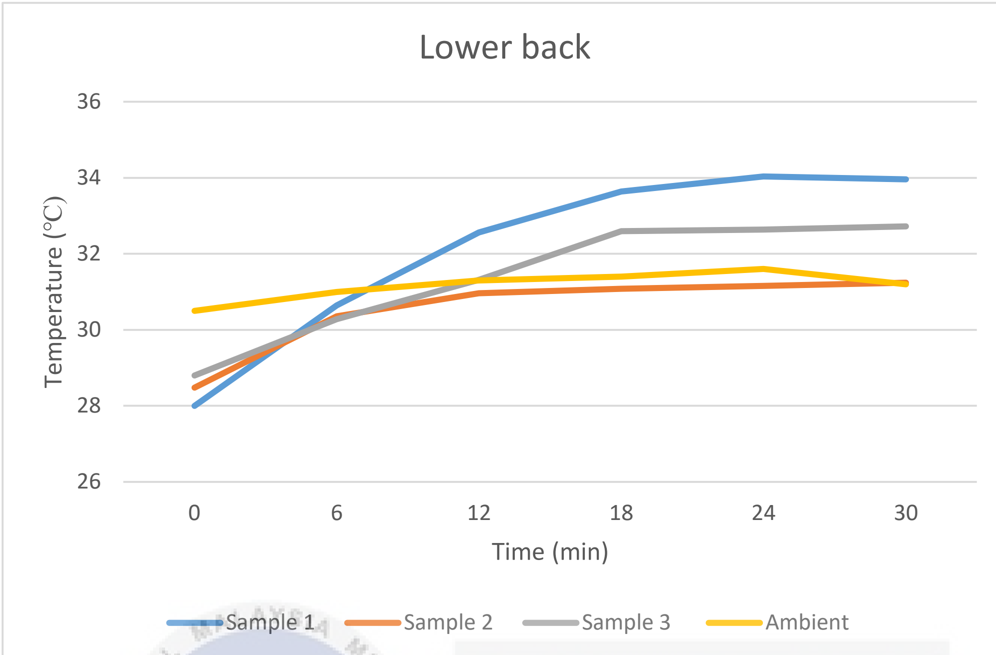


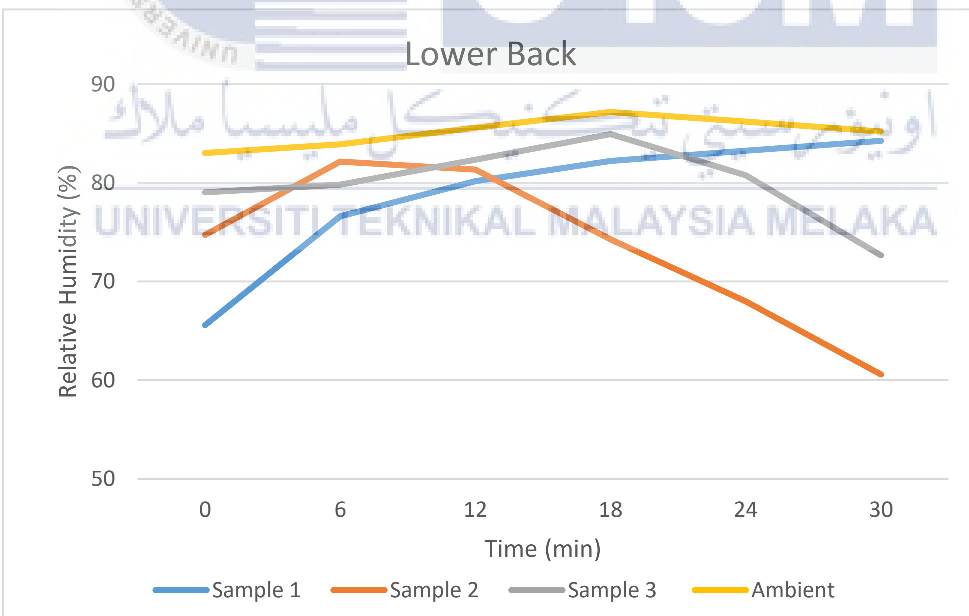

Center Right
35
33
31
29
27
Temperature (°C)
0
6
12
18
24
30
Time (min)
Sample 1
Sample 2
Sample 3
Ambient

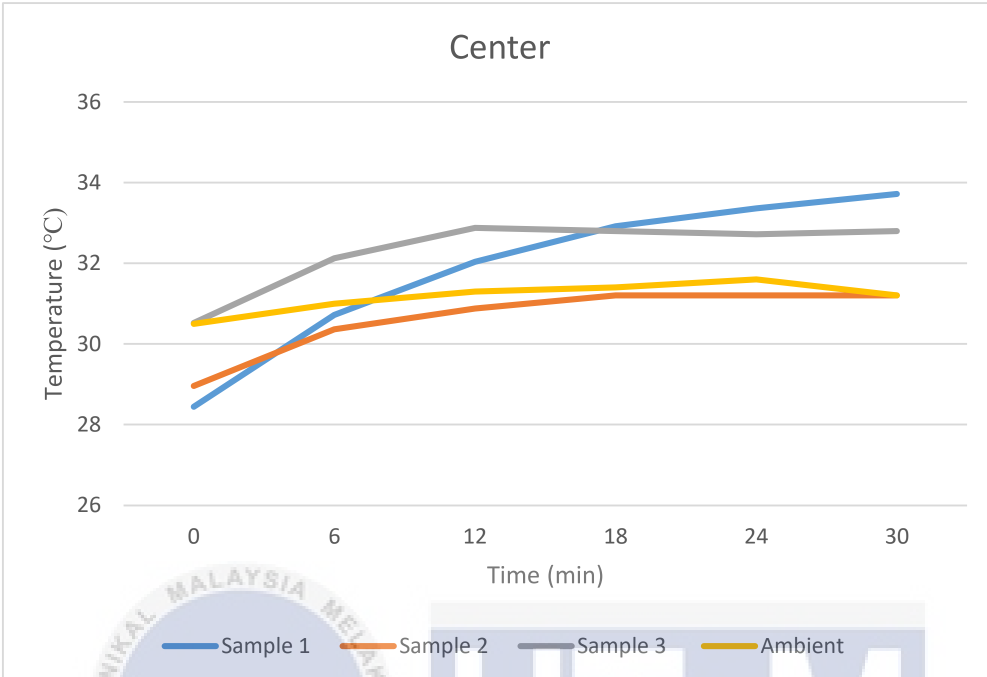

Center right
100
90
80
70
60
50
Relative Humidity (%)
0
6
12
18
24
30
Time (min)
Sample 1
Sample 2
Sample 3
Ambient

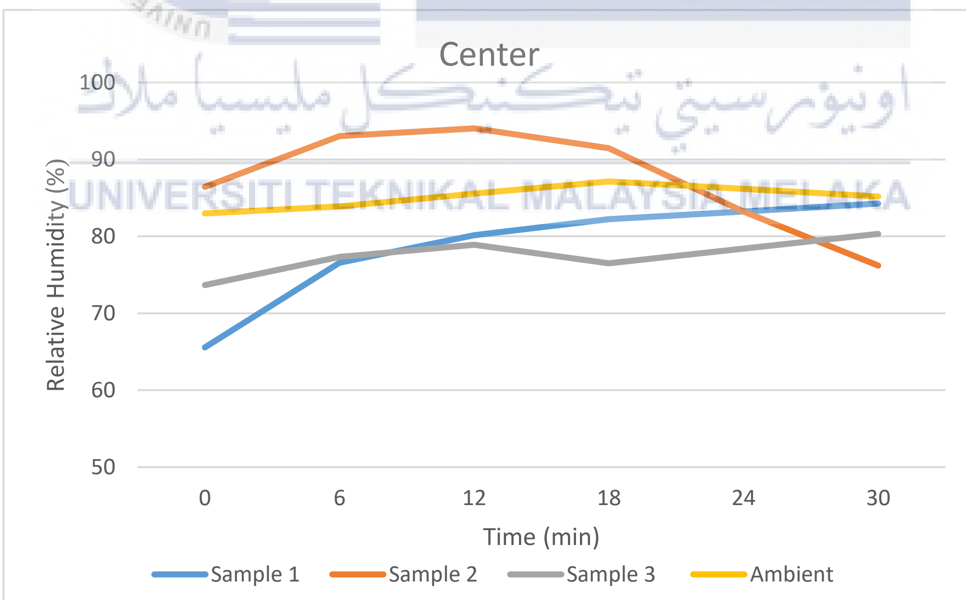

Back Right
Temperature (°C)
32
30
28
26
0
6
12
18
24
30
Time (min)
Sample 1
Sample 2
Sample 3
Ambient

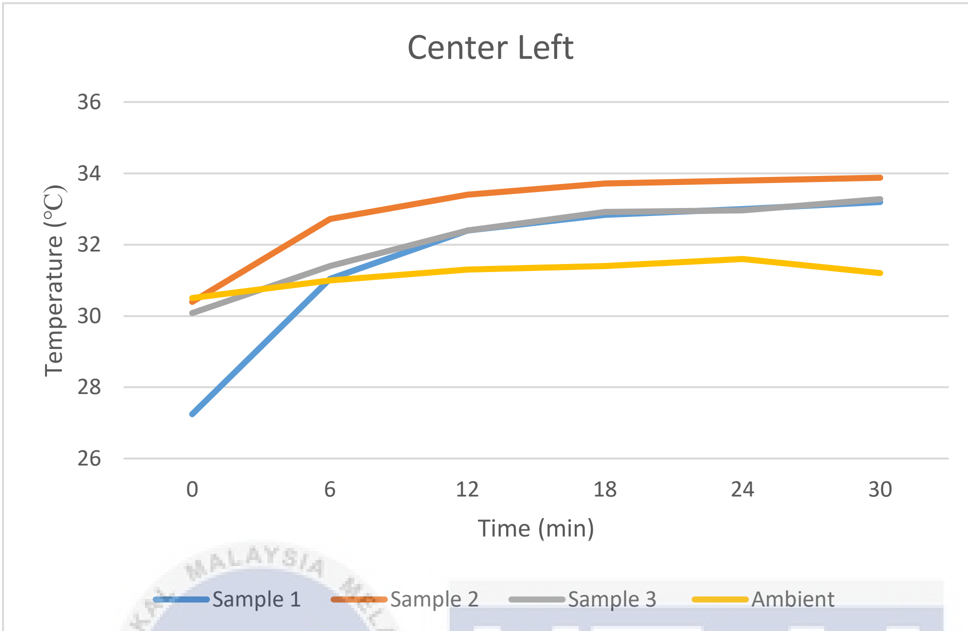

Back Right
Relative Humidity (%)
90
80
70
60
50
0
6
12
18
24
30
Time (min)
Sample 1
Sample 2
Sample 3
Ambient

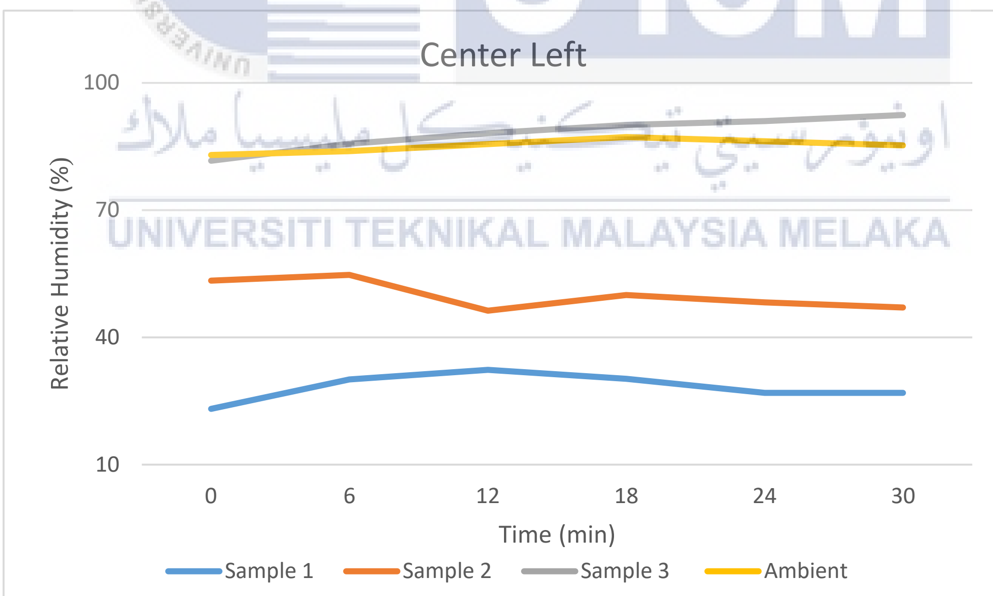

Lower back
36
34
32
30
28
26
Temperature (°C)
0
6
12
18
24
30
Time (min)
Sample 1
Sample 2
Sample 3
Ambient


Lower Back
90
80
70
60
50
Relative Humidity (%)
0
6
12
18
24
30
Time (min)
Sample 1
Sample 2
Sample 3
Ambient

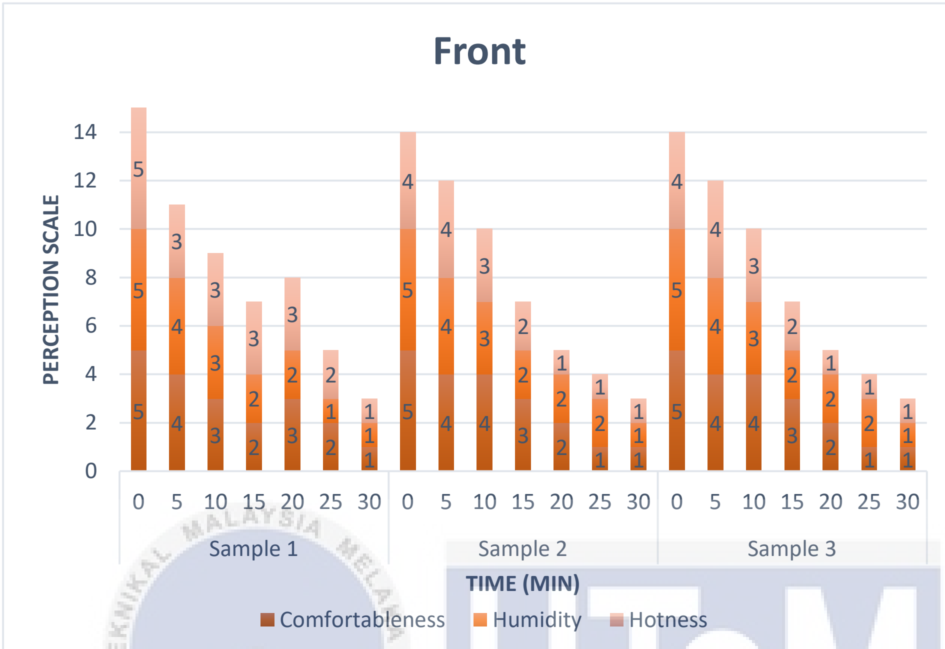

Center
36
34
32
30
28
26
Temperature (°C)
0
6
12
18
24
30
Time (min)
Sample 1
Sample 2
Sample 3
Ambient

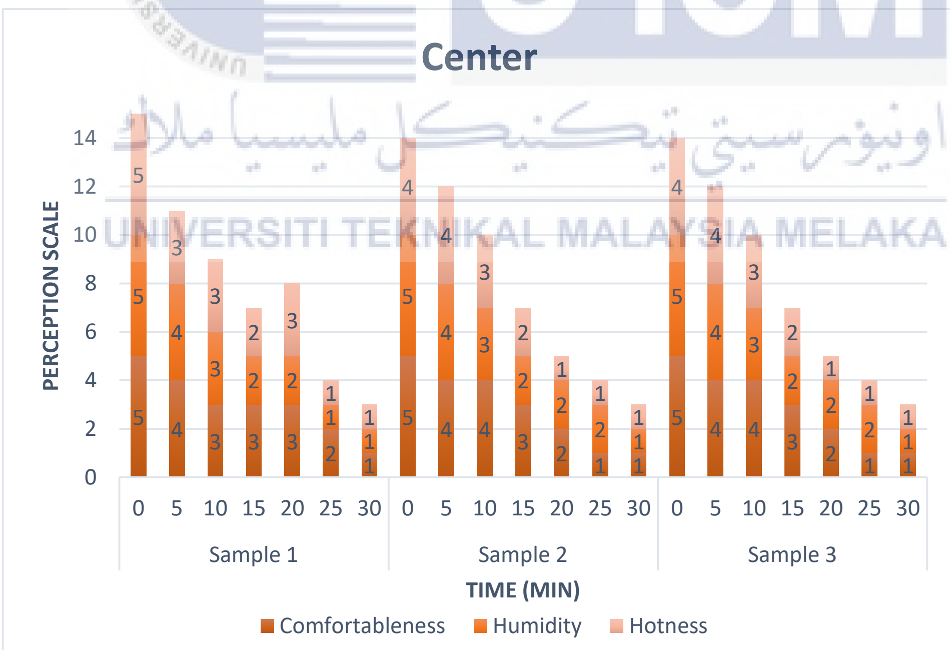

Center
100
90
80
70
60
50
Relative Humidity (%)
0
6
12
18
24
30
Time (min)
Sample 1
Sample 2
Sample 3
Ambient

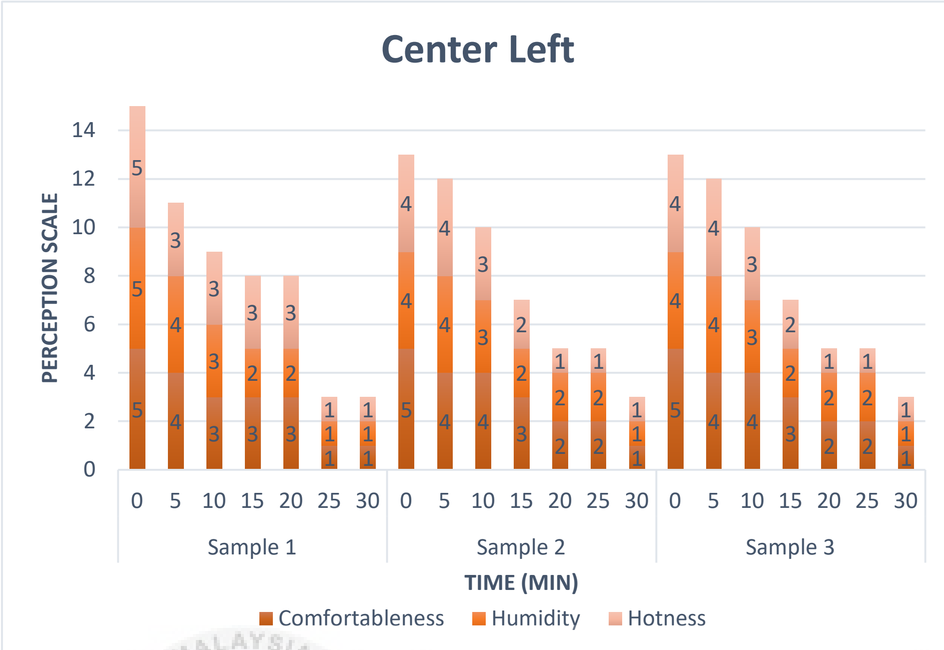

Center Left
36
34
32
30
28
26
Temperature (°C)
0
6
12
18
24
30
Time (min)
Sample 1
Sample 2
Sample 3
Ambient

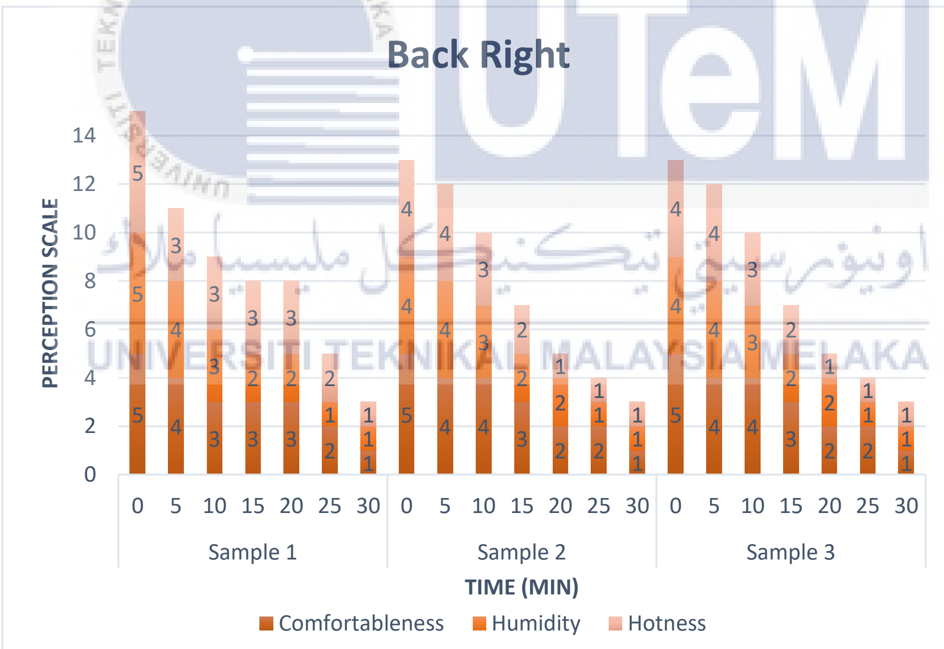

Center Left
100
70
40
10
Relative Humidity (%)
0
6
12
18
24
30
Time (min)
Sample 1
Sample 2
Sample 3
Ambient

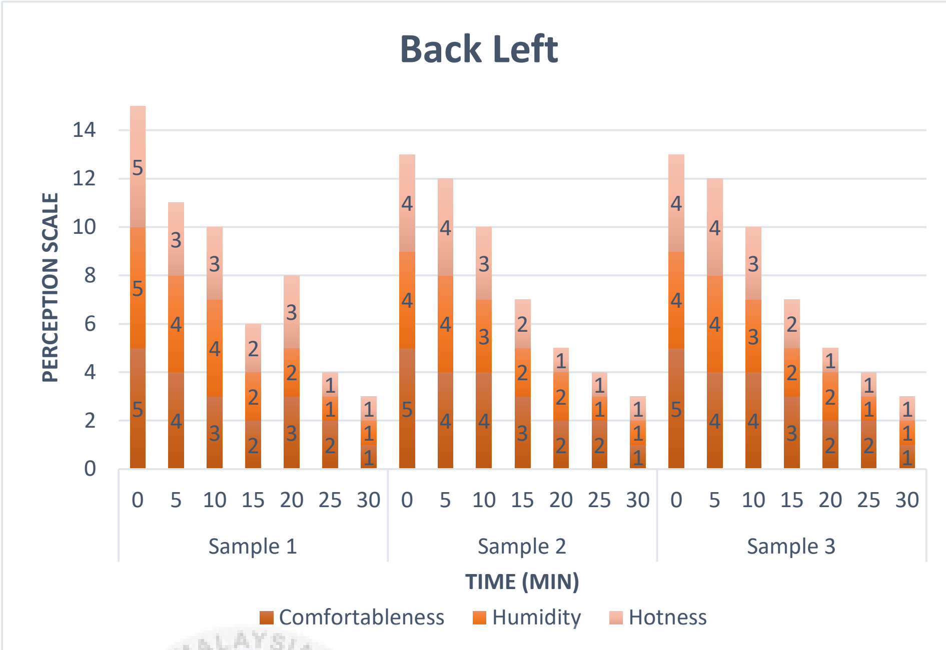
Human perception scale for subject 3

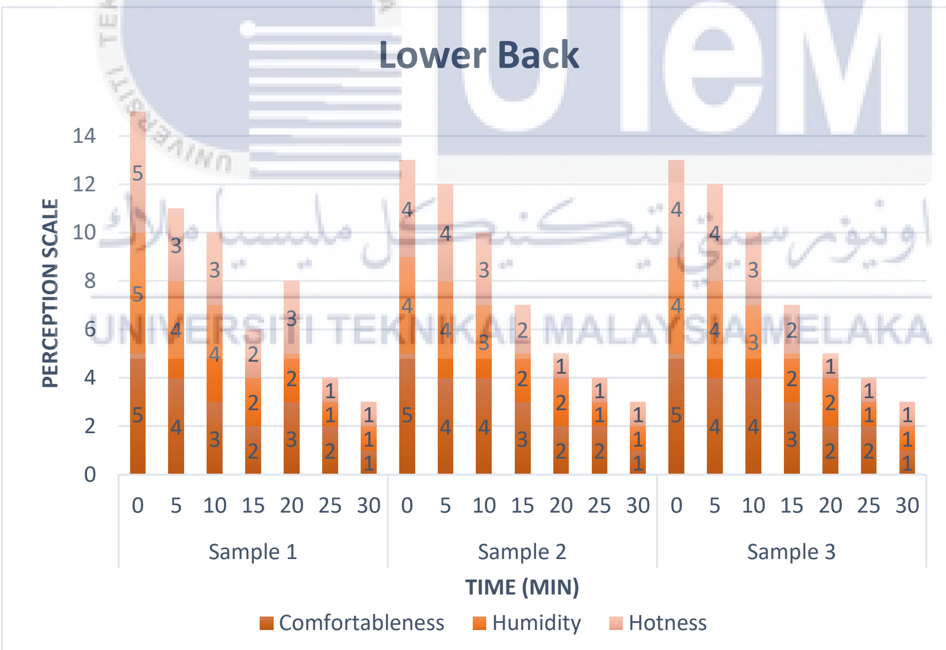





Center Left
PERCEPTION SCALE
0 2 4 6 8 10 12 14
0 5 10 15 20 25 30
Sample 1
Sample 2
Sample 3
TIME (MIN)
Comfortableness
Humidity
Hotness


Back Right
PERCEPTION SCALE
0 2 4 6 8 10 12 14
0 5 10 15 20 25 30
Sample 1
Sample 2
Sample 3
TIME (MIN)
Comfortableness
Humidity
Hotness

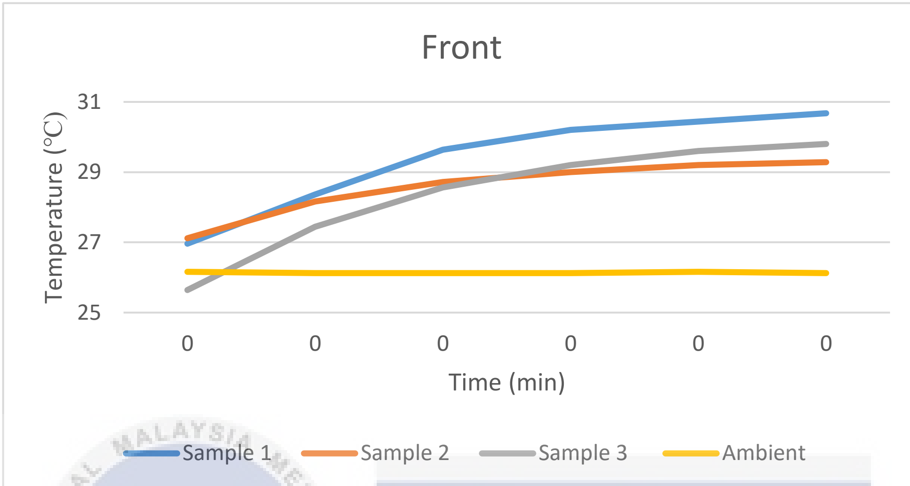

Back Left
PERCEPTION SCALE
TIME (MIN)
Sample 1
Sample 2
Sample 3
Comfortableness
Humidity
Hotness


Lower Back
PERCEPTION SCALE
TIME (MIN)
Sample 1
Sample 2
Sample 3
Comfortableness
Humidity
Hotness

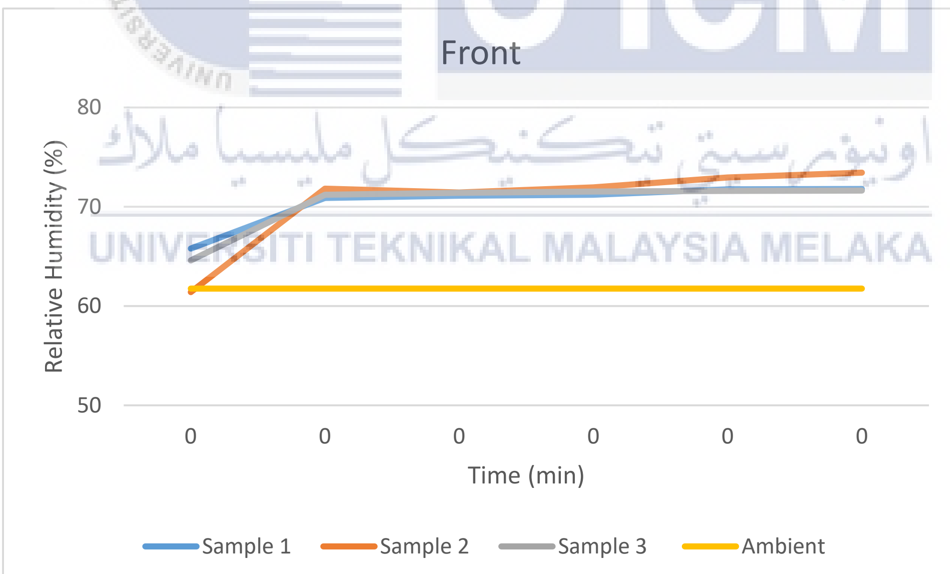
Subject 4

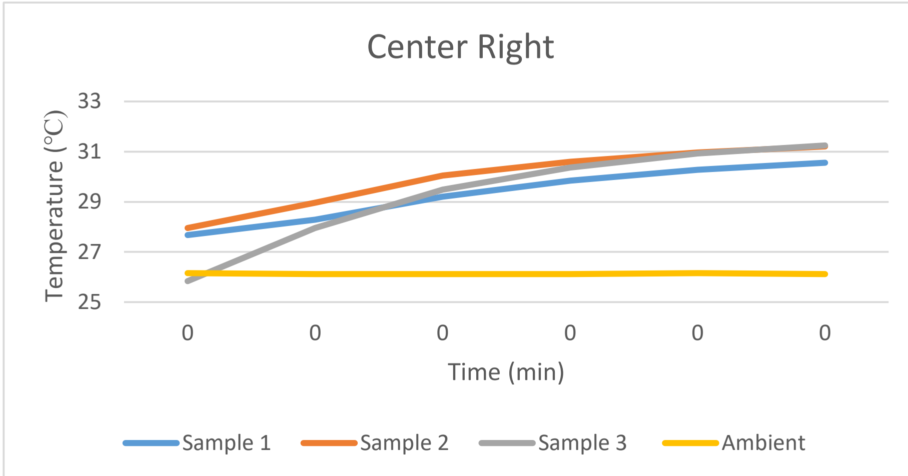
Helmet temperature and relative humidity graphs

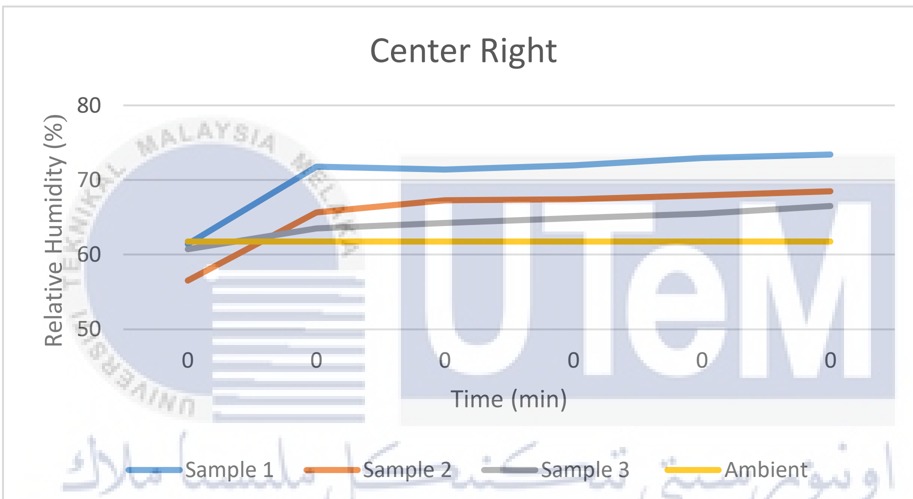
Temperature vs time graph

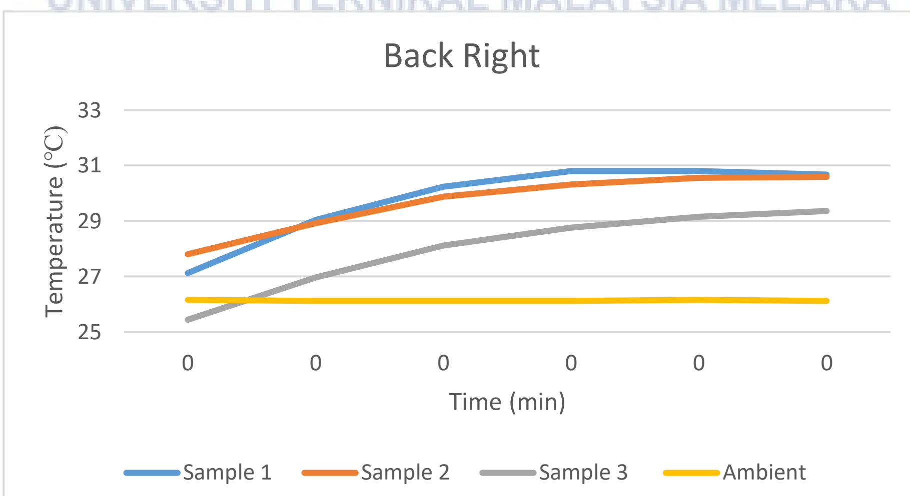


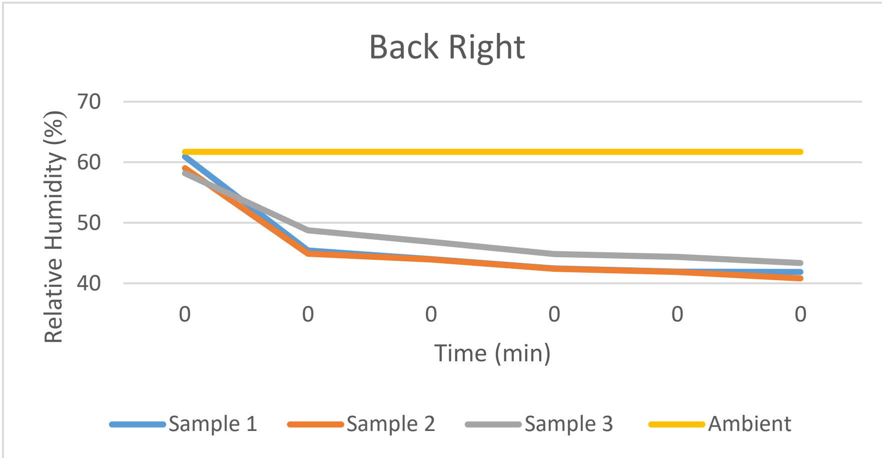
Relative Humidity vs time graph

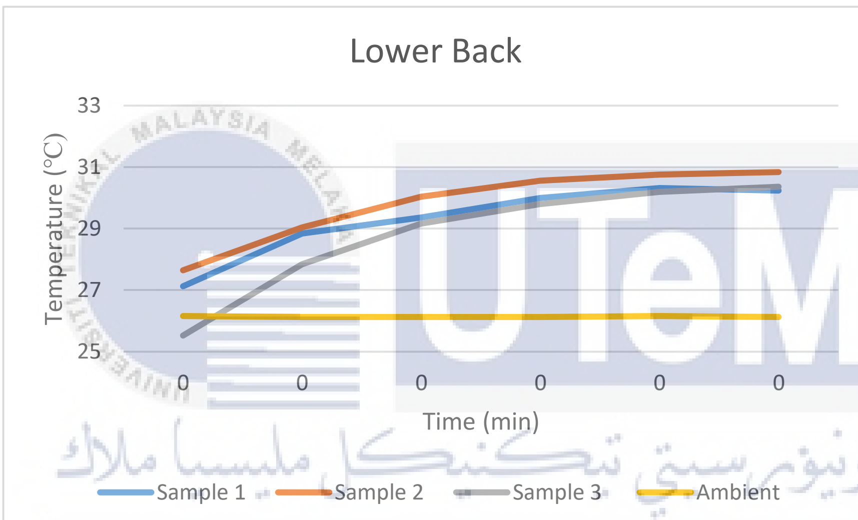


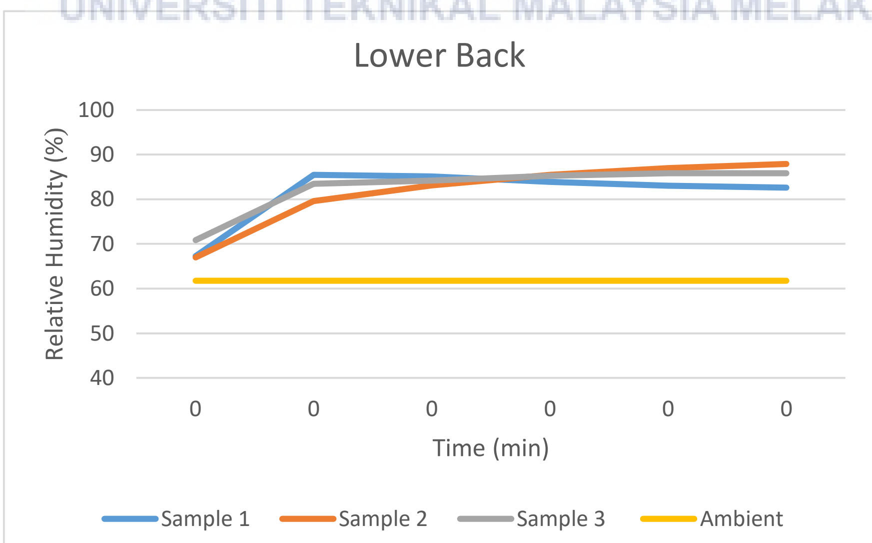

Center Right
33
31
29
27
25
Temperature (°C)
0 0 0 0 0 0
Time (min)
Sample 1
Sample 2
Sample 3
Ambient

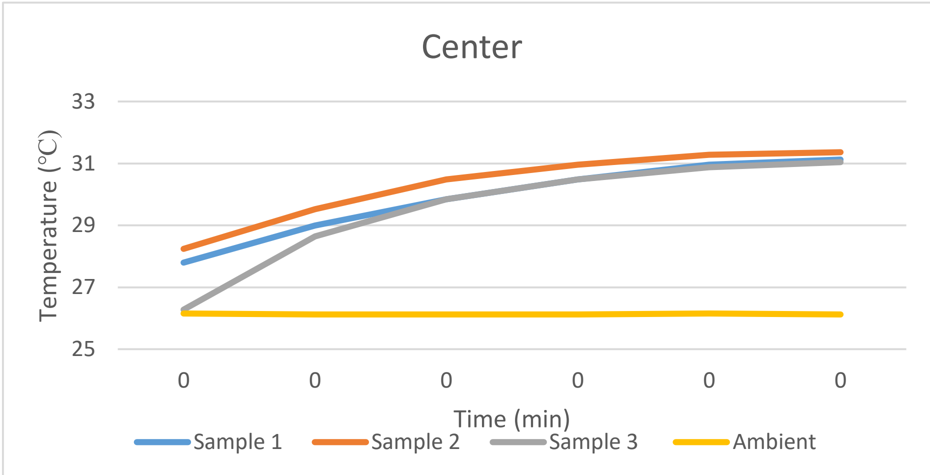

Center Right
80
70
60
50
Relative Humidity (%)
0 0 0 0 0 0
Time (min)
Sample 1
Sample 2
Sample 3
Ambient


Back Right
33
31
29
27
25
Temperature (°C)
0 0 0 0 0 0
Time (min)
Sample 1
Sample 2
Sample 3
Ambient

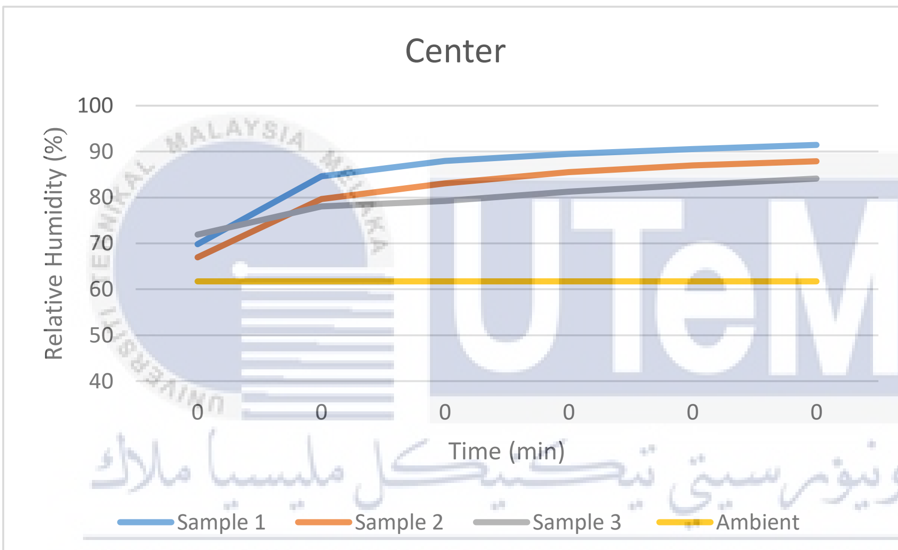

Back Right
Relative Humidity (%)
70
60
50
40
0
0
0
0
0
0
Time (min)
Sample 1
Sample 2
Sample 3
Ambient


Lower Back
Temperature (°C)
33
31
29
27
25
0
0
0
0
0
0
Time (min)
Sample 1
Sample 2
Sample 3
Ambient

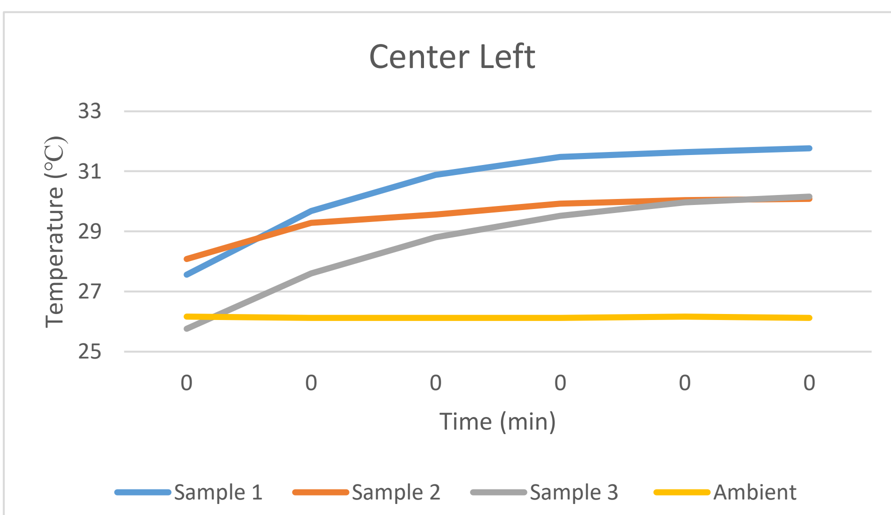

Lower Back
Relative Humidity (%)
100
90
80
70
60
50
40
0
0
0
0
0
0
Time (min)
Sample 1
Sample 2
Sample 3
Ambient



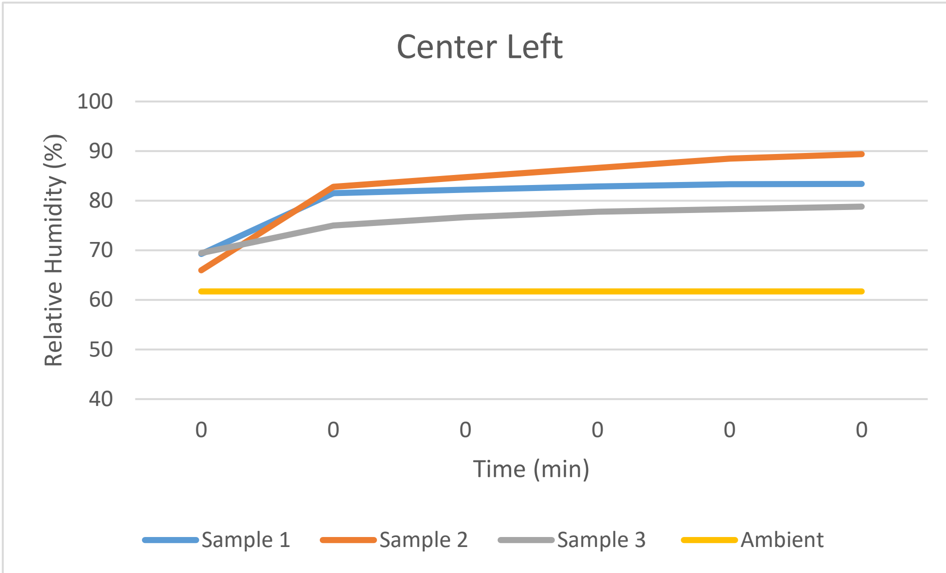
Center
Temperature (°C)
33
31
29
27
25
0
0
0
0
0
0
Time (min)
Sample 1
Sample 2
Sample 3
Ambient



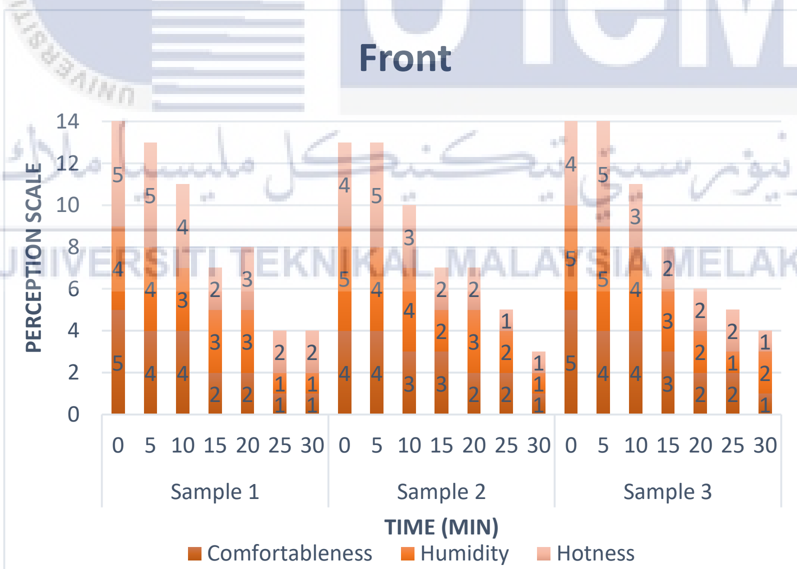
Center
Relative Humidity (%)
100
90
80
70
60
50
40
0
0
0
0
0
0
Time (min)
Sample 1
Sample 2
Sample 3
Ambient

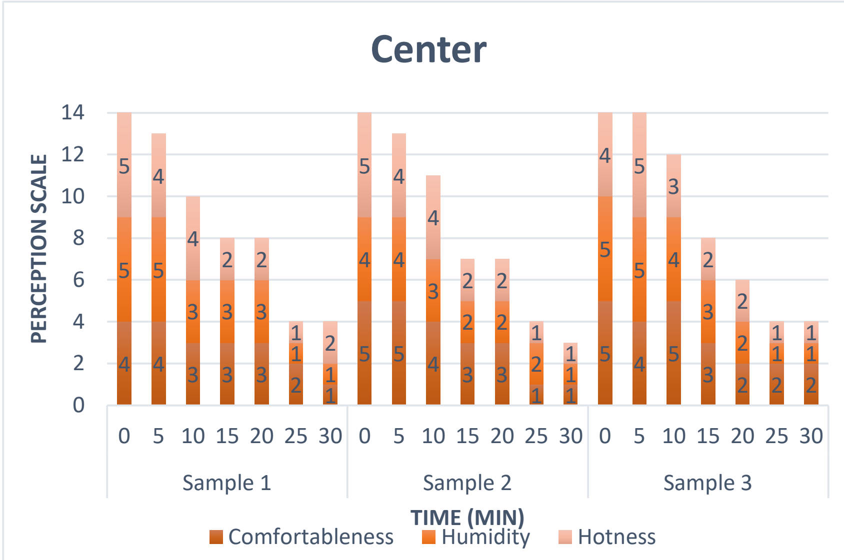


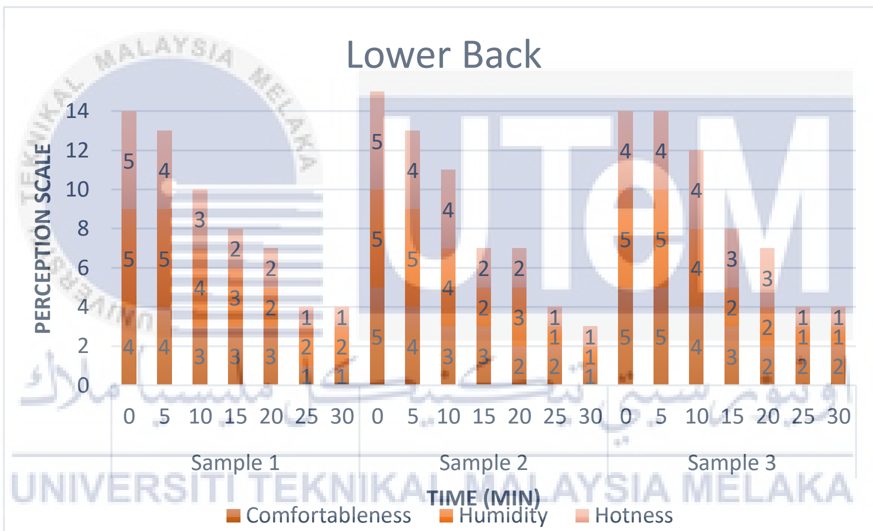
Center Left
Temperature (°C)
33
31
29
27
25
0
0
0
0
0
0
Time (min)
Sample 1
Sample 2
Sample 3
Ambient

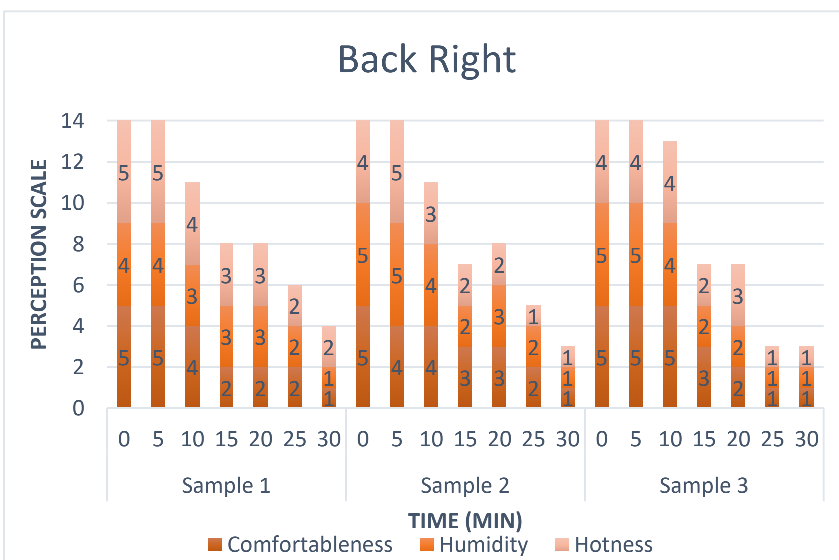


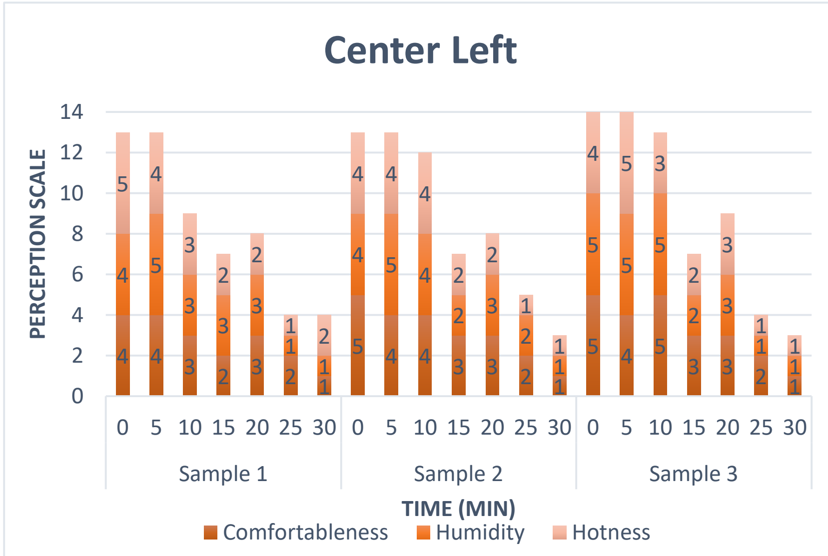
Human perception scale for subject 4

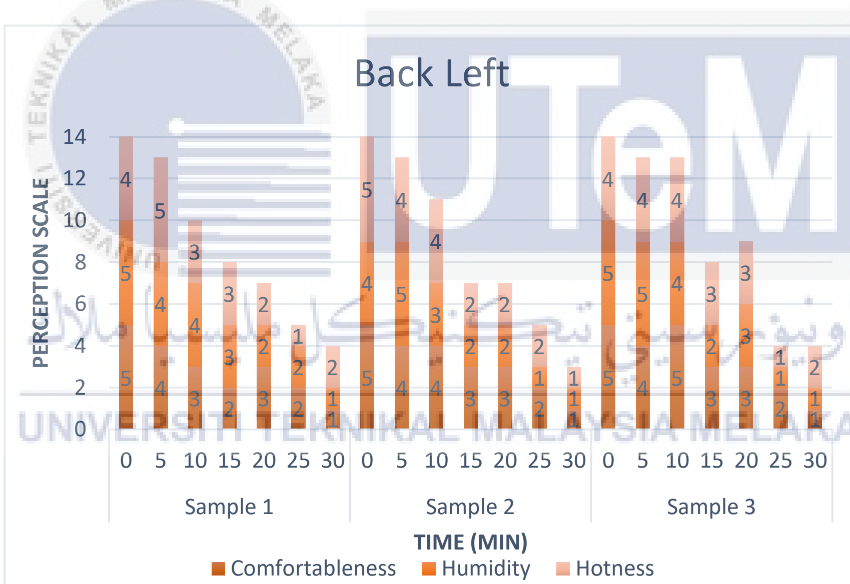



Center
PERCEPTION SCALE
14 12 10 8 6 4 2 0
0 5 10 15 20 25 30
Sample 1
Sample 2
Sample 3
TIME (MIN)
Comfortableness
Humidity
Hotness


Lower Back
PERCEPTION SCALE
14 12 10 8 6 4 2 0
0 5 10 15 20 25 30
Sample 1
Sample 2
Sample 3
TIME (MIN)
Comfortableness
Humidity
Hotness


Back Right
PERCEPTION SCALE
14 12 10 8 6 4 2 0
0 5 10 15 20 25 30
Sample 1
Sample 2
Sample 3
TIME (MIN)
Comfortableness
Humidity
Hotness

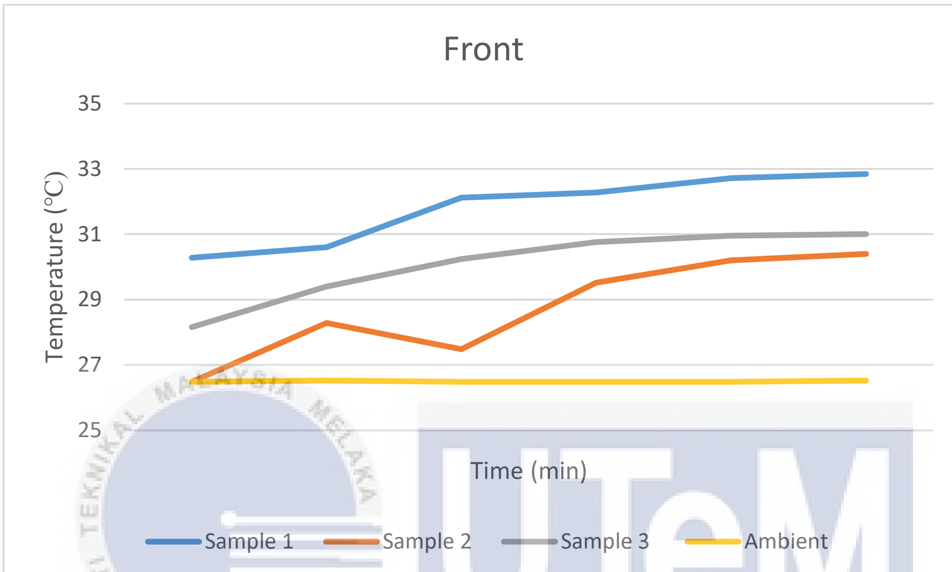

Center Left
PERCEPTION SCALE
TIME (MIN)
Sample 1
Sample 2
Sample 3
Comfortableness
Humidity
Hotness


Back Left
PERCEPTION SCALE
TIME (MIN)
Sample 1
Sample 2
Sample 3
Comfortableness
Humidity
Hotness

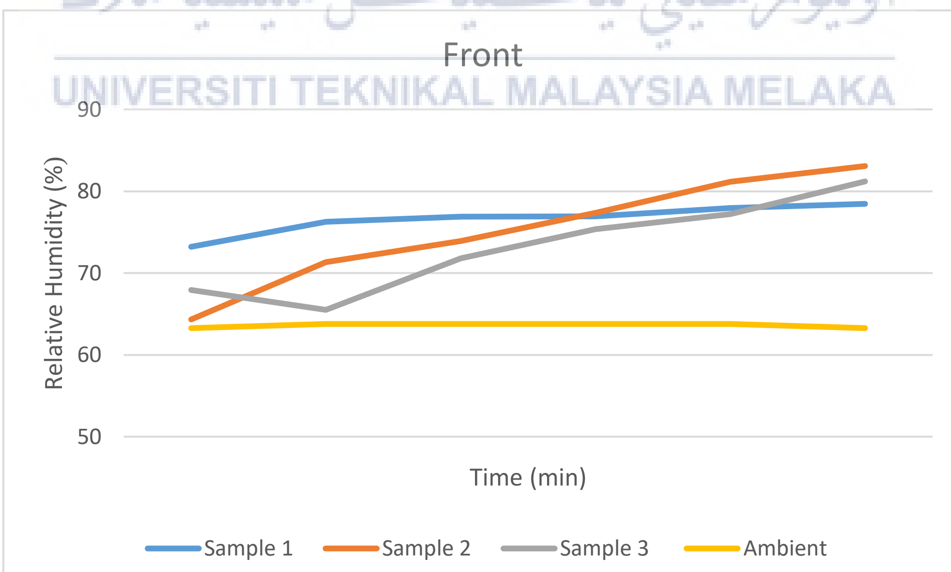
Results for subject 5

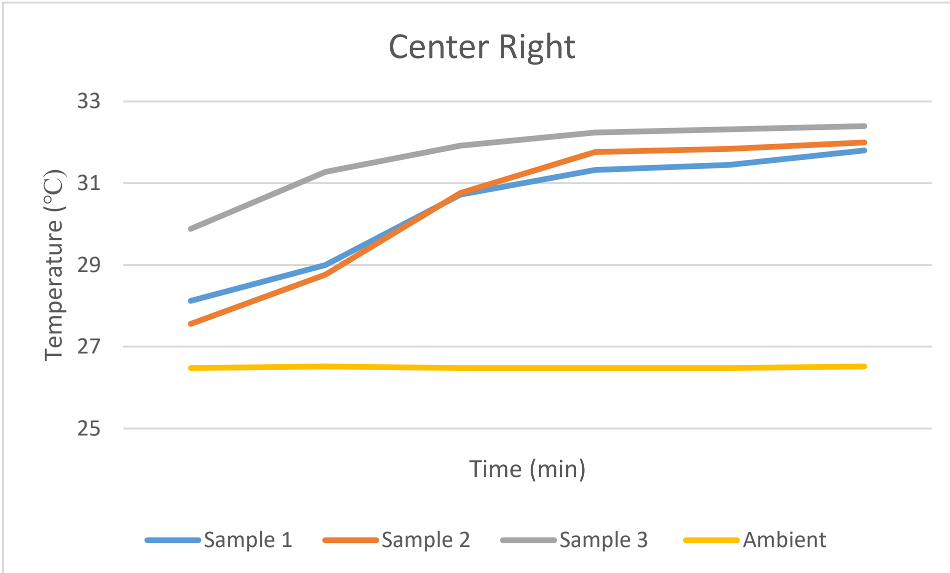
Helmet temperature and relative humidity

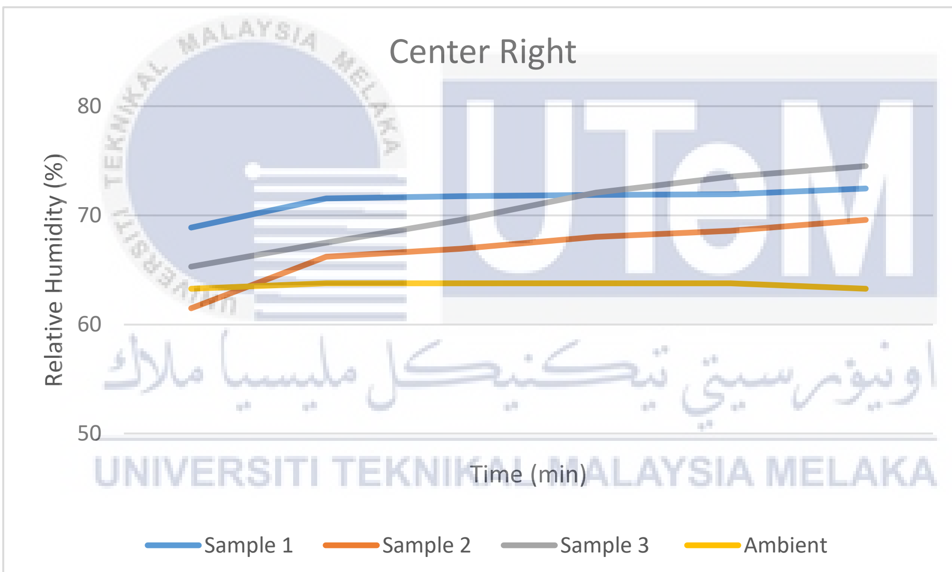
Temperature vs time graph

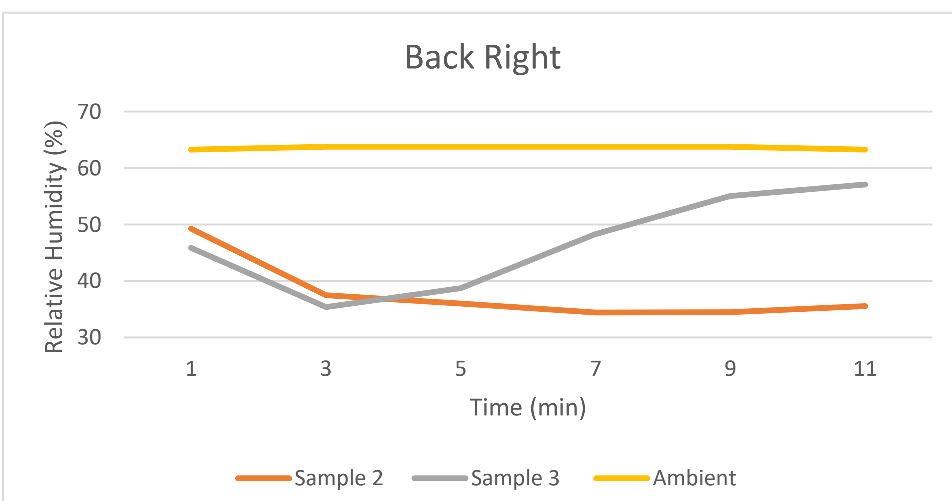


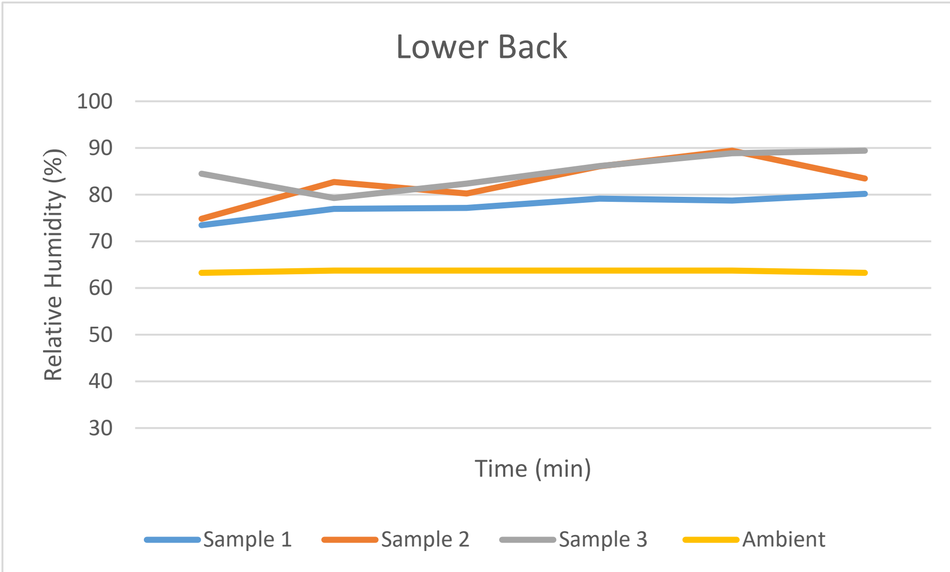
Relative humidity vs time graph

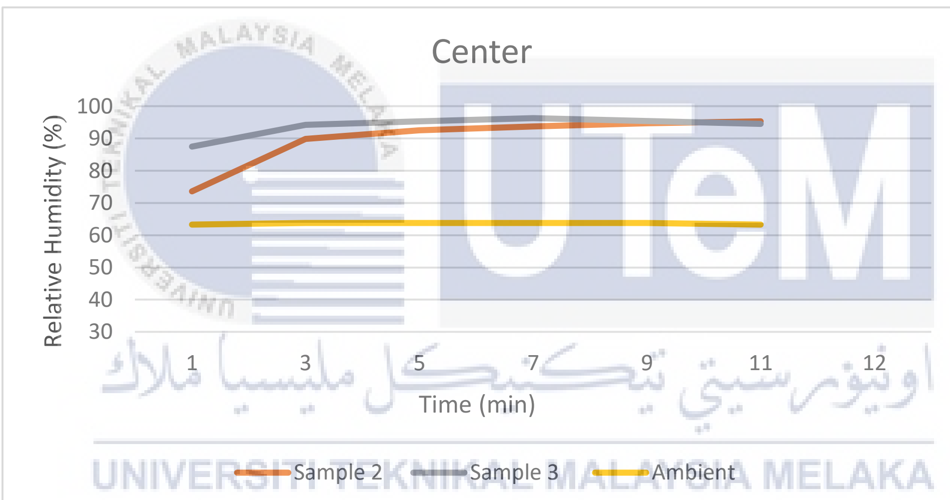


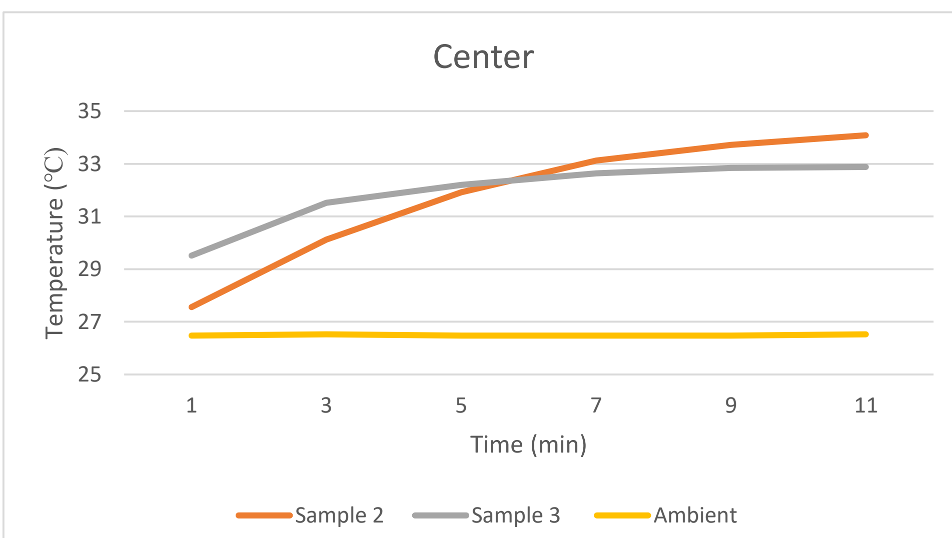

Center Right
33
31
29
27
25
Temperature (°C)
Time (min)
Sample 1
Sample 2
Sample 3
Ambient

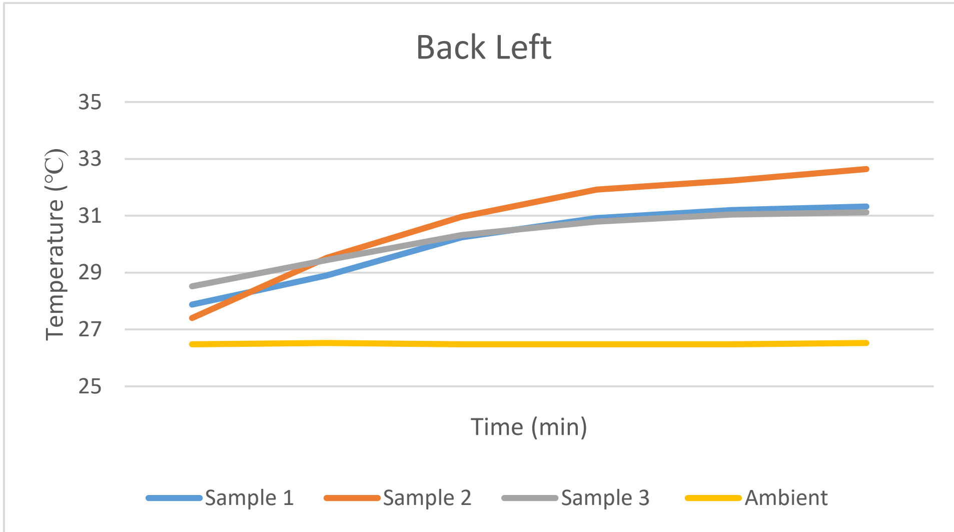

Center Right
80
70
60
50
Relative Humidity (%)
Time (min)
Sample 1
Sample 2
Sample 3
Ambient

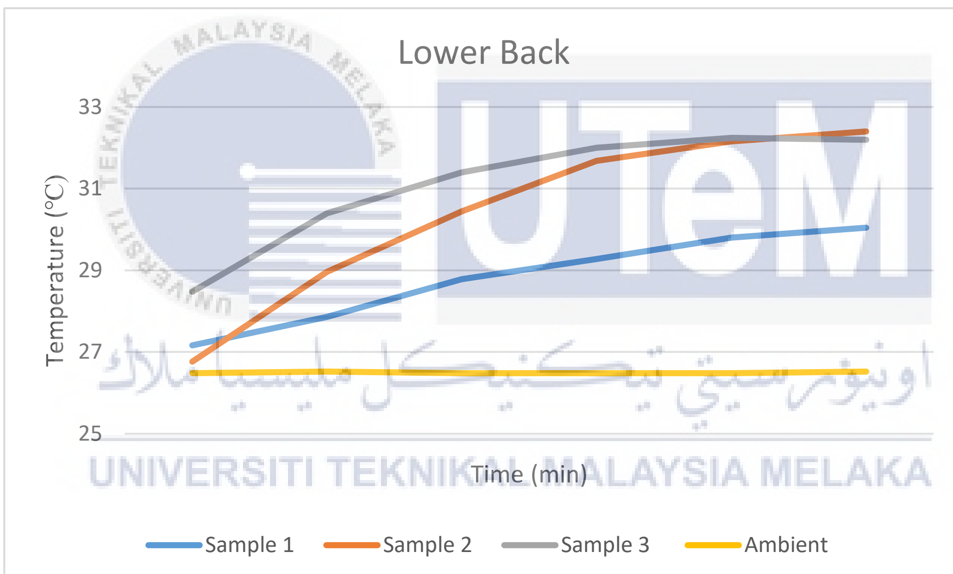

Back Right
70
60
50
40
30
Relative Humidity (%)
1
3
5
7
9
11
Time (min)
Sample 2
Sample 3
Ambient


Lower Back
Relative Humidity (%)
100
90
80
70
60
50
40
30
Time (min)
Sample 1
Sample 2
Sample 3
Ambient

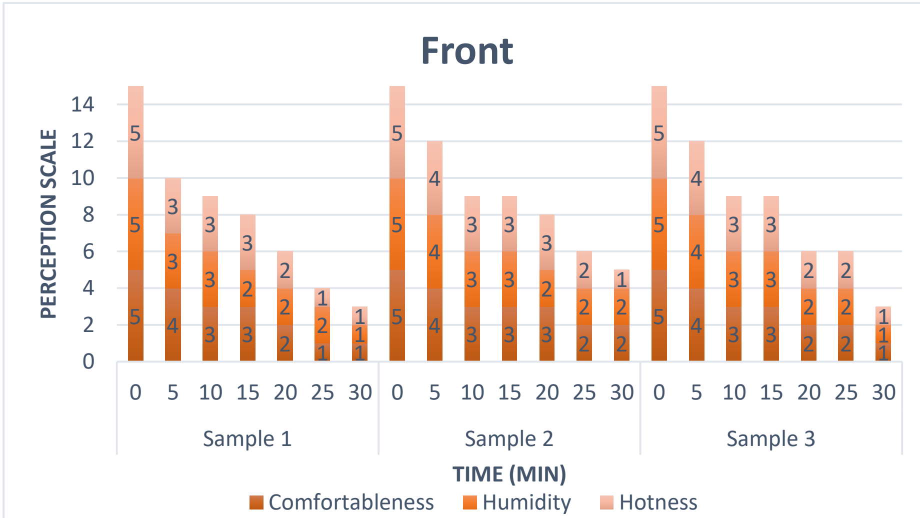

Center
Relative Humidity (%)
100
90
80
70
60
50
40
30
1
3
5
7
9
11
12
Time (min)
Sample 2
Sample 3
Ambient

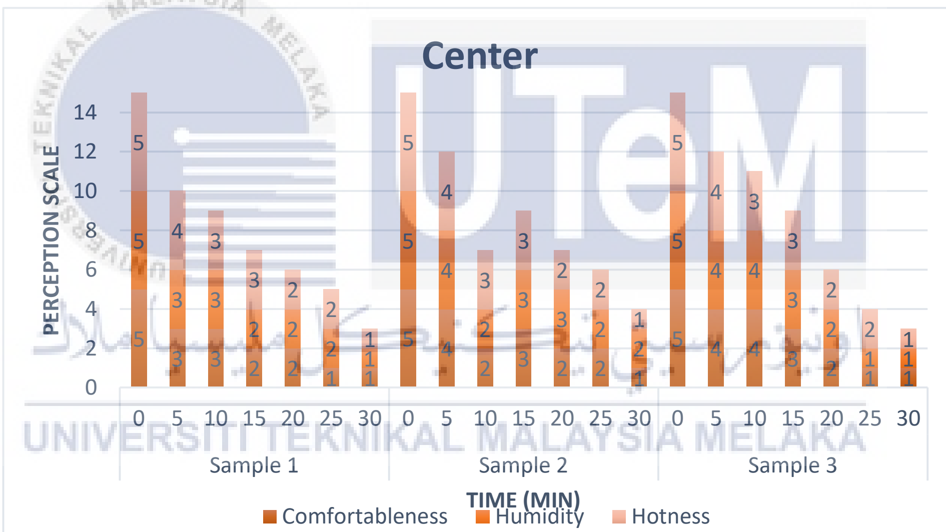

Center
Temperature (°C)
35
33
31
29
27
25
1
3
5
7
9
11
Time (min)
Sample 2
Sample 3
Ambient

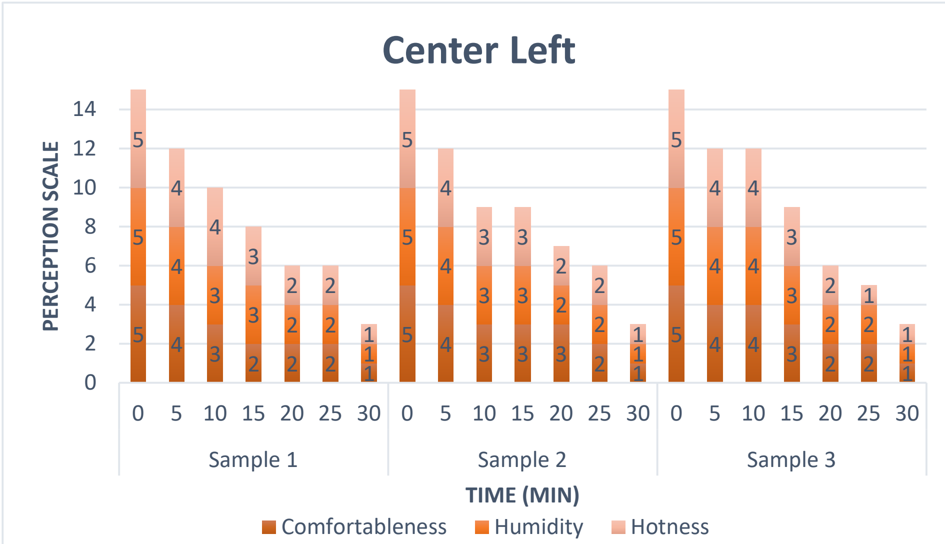

Back Left
35
33
31
29
27
25
Temperature (°C)
Time (min)
Sample 1
Sample 2
Sample 3
Ambient

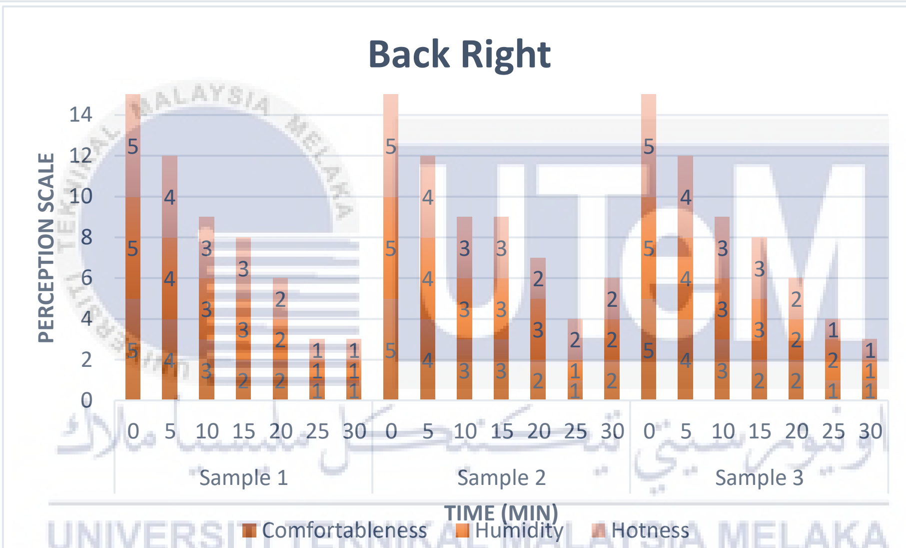

Lower Back
33
31
29
27
25
Temperature (°C)
Time (min)
Sample 1
Sample 2
Sample 3
Ambient

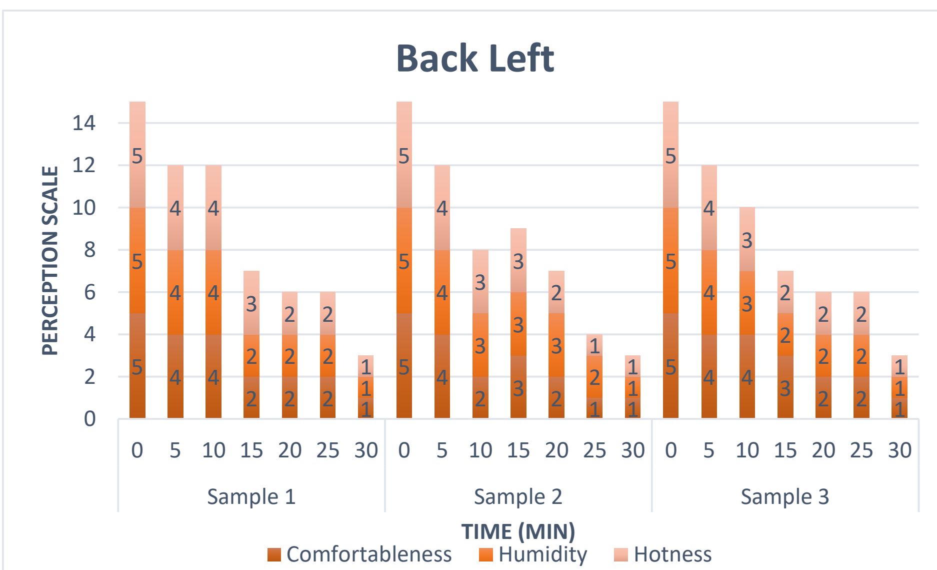
Human perception scale for subject 5

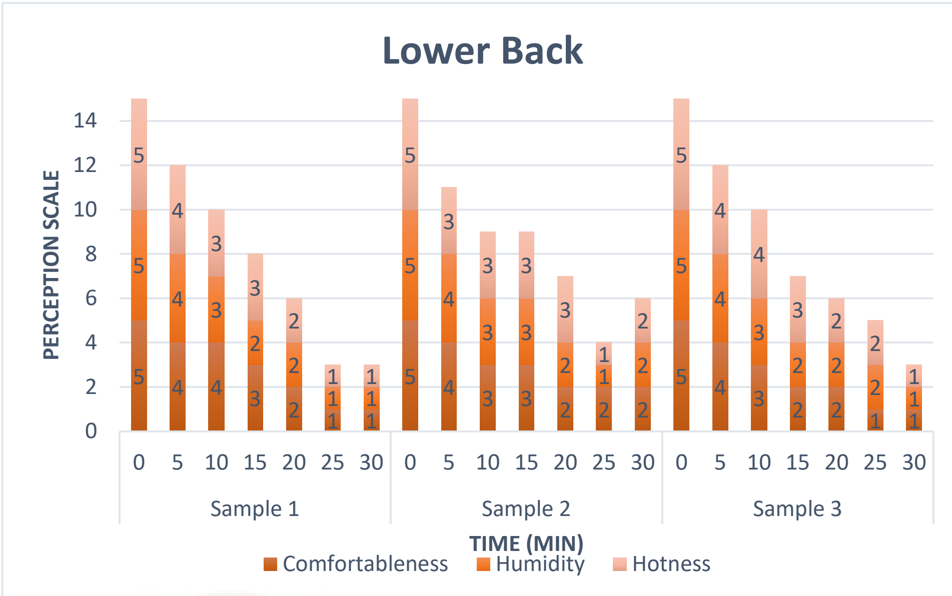




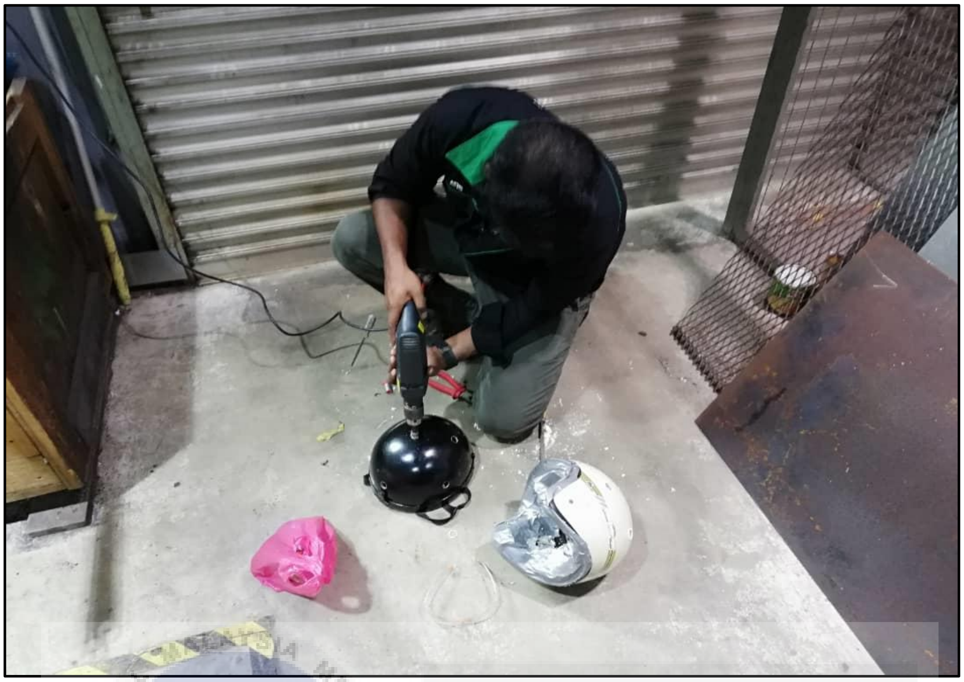

Center Left
PERCEPTION SCALE
0 2 4 6 8 10 12 14
0 5 10 15 20 25 30
Sample 1 Sample 2 Sample 3
TIME (MIN)
Comfortableness Humidity Hotness


Back Right
PERCEPTION SCALE
0 2 4 6 8 10 12 14
0 5 10 15 20 25 30
Sample 1 Sample 2 Sample 3
TIME (MIN)
Comfortableness Humidity Hotness


Back Left
PERCEPTION SCALE
0 2 4 6 8 10 12 14
0 5 10 15 20 25 30
Sample 1 Sample 2 Sample 3
TIME (MIN)
Comfortableness Humidity Hotness



Work Progress



Example list of data

timestamp	runtime [ms]	device id	sensor type	serial	relative humidity [%RH]	temperature [degC]
2019-03-26T15:31:24.769	0	COM4.1	SHT7x	4.95E+13	87.46	29.52
2019-03-26T15:31:24.769	0	COM4.2	SHT7x	9.75E+12	73.3	28.52
2019-03-26T15:31:24.769	0	COM4.3	SHT7x	4.85E+13	62.81	26.68
2019-03-26T15:31:26.443	1674	COM3.1	SHT7x	8.14E+11	67.94	28.16
2019-03-26T15:31:26.443	1674	COM3.2	SHT7x	8.14E+12	65.31	29.88
2019-03-26T15:31:26.443	1674	COM3.3	SHT7x	6.34E+12	45.86	28.56
2019-03-26T15:31:26.443	1674	COM3.4	SHT7x	8.24E+12	84.49	28.48
2019-03-26T15:31:54.669	29900	COM4.1	SHT7x	4.95E+13	89.32	29.76
2019-03-26T15:31:54.669	29900	COM4.2	SHT7x	9.75E+12	74.27	28.6
2019-03-26T15:31:54.669	29900	COM4.3	SHT7x	4.85E+13	62.8	26.64