International Journal of Sciences & Applied Research

International Journal of Sciences & Applied Research

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Wicking and drying behavior of different weft knitted fabrics

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Abstract

Generally knitted fabrics are worn next to the human skin. So the way the wearer would feel depends on the nature of the fabric. When the temperature of the surroundings increases, the human body undergoes some changes to keep the body cool and sweating is the most common way of releasing the heat through by secreting a type of fluid to the skin and evaporating the sweat which reduces the body temperature and cools the body. But instead of evaporating, if the sweat is just absorbed by the worn cloth and kept in contact with the skin by wet cloth, it causes discomfort and the body cooling process doesn't take place properly. Tests were done to measure the drying rate of single jersey plain and 1×1 rib fabric and the later was found better. Fabrics with higher stitch length also showed better drying rate for both fabric structures. The reasons behind these results have been discussed in this work.

Keywords: Comfort, Knitted fabric structures, Course, Wales, Fabric GSM, Wick-ability, Dry-ability

Introduction

When the temperature increases, sweating is the most common problem every person faces. This happens because excessive temperature of the surroundings as it increases the temperature of the human body than normal body temperature (about 37 degrees Celsius), the body undergoes a series of changes to help keep it cool [1]. Sweating is the most common of it. Not only high temperature, but also some other reasons such as heavy work or exercise, foods which are burnt in the body and energy is produced in the form of heat, nervousness etc can cause sweat. Whenever the body temperature increases due to these reasons, a type of fluid is secreted on the skin which actually works to cool the body down if the fluid evaporates [1].This evaporation heavily depends on humidity as highly humid surrounding declines absorption of the sweat. But when the sweat evaporates, it reduces the body temperature and gives the cool comfortable feeling. This evaporation is also delayed because of the garments we wear. The sweat comes out on the skin and being taken by the garment. If the garment is made of absorbent material like cotton, the fabric tends to cling on to skin which causes discomfort. To give comfort, the sweat has to go through the garment inner surface to outer surface and then gets evaporated from there[2]. Otherwise the fabric stays wet for a prolonged period. It also causes bad odor as the retained sweat is favorable for bacteria growth. Since sweat cannot be stopped, the only way to feel comfortable is evaporating the sweat from the body and keep the body dry as much as possible. Since the skin comes in contact with the fabric next to the skin, the fabric has to take away the sweat away from skin. But the most commonly used cotton fabric cannot do it as cotton fabric can absorb the sweat better than anything else but it becomes wet and stay wet for so long due to its highly absorbent nature and it causes discomfort to the wearer. So, drying of the fabric should be a highly significant factor in this scenario. Evaporation or drying rate depends on the amount of water taken by the fabric, the fibres in the yarn which constitutes the fabric and the relative humidity of the atmosphere [4, 5].The last cause is natural and very little can be done about itbut the other two causes can be controlled. First of all the raw material plays the most significant role in liquid absorption. As said earlier cotton, wool etc are quite hydrophilic in nature and absorbs water more than hydrophobic fibres like polyester, nylon etc synthetic fibres. Absorption of liquid depends heavily on the moisture regain of the fibre as fibres with high moisture regain absorb more liquid. So the sweat can be absorbed most by this kind of fibre. But the problem is, these fibre tend to retain the liquid due to having high moisture regain and it lessens evaporation rate So, hydrophobic fibre may be the answer from this point of view as it won't tend to retain it's slow absorbent power is a matter of concern as the suspect is the sweat would not be absorbed from the body at all. There comes the phenomenon called wicking in to consideration. Wicking is the spontaneous flow of a liquid in a porous substance, which is driven by capillary forces [6].Wicking or liquid spreading quality helps transferring the sweat from body. The man-made fibres have a very regular cross section and smooth surface which help wicking property [7]. This property actually helps spreading the absorbed liquid in a large surface area of the fabric through the fabric and yarn pores or void spaces and it is known that, evaporating liquid from larger area is easier than evaporating from small area. So, wicking behavior can also affect drying property of the fabric[8].For high dry-ability, the fabric needs to have better wick-ability. Other factors which can affect wicking behaviors are yarn twist and fabric structure [9]. Yarn twist can be a major factor as it has been found that wicking or the motion of liquid through fabric depends on the void spaces between the fibers in a yarn (intra-yarn) [10]. Yarn made of highly absorbent fibres absorb liquid and swells to fill the void in yarn and deters liquid movement. Again, high twist in yarn would make the yarn compact and reduce void spaces which would also deter liquid movement through the yarn. So, low twisted yarn may help wicking behavior. The other factor is fabric structure. Actually the voids or free spaces in a fabric are heavily dependent on the fabric structure. Fabric with loose structure is expected to offer more free spaces in it which may help wick-ability of the fabric. In knitted fabric structures, weft knitted fabrics are known for comparatively loose and comfortable behavior than warp knitted fabrics and in weft knitted fabrics, there are single and double jersey structures. Here, some tests are to be done here to find out how much effect fabric structure can have on wick-ability and dry-ability of a fabric.

Materials and methods

Weft knitted fabrics are of different types as already mentioned, they are single jersey and double jersey. Among single jersey designs, derivatives are made by using knit, tuck and miss loops at different places. The same is done in double jersey structures too. In double jersey, Rib and Interlocks are mostly and its derivatives are also made by using different loops. Here, only single jersey plain and simple Rib or 1×1 Rib are used as samples made of 100% cotton. The main concern is to find out the effect of looseness of fabric on wick-ability different stitch length for samples and also the effect of fabric structure on wick-ability to determine the suitable fabric structure among the used two structures so that it can be determined which structure can take away sweat from the skin and also evaporate the sweat in the surroundings quickly. Since the main concern of this work is to find out the effect of stitch length and fabric structure, the samples are not scoured because it would not give correct result as cotton fibre itself can affect wick-ability when it has its full absorbent power. The tests are to be done are;

01. Wicking test
02. Drying rate test

Materials

The following Table 1 will show the used samples with specifications.

Methods

Capillarity Test or Wicking Test

There are many tiny spaces between the fibres of the fabric or small openings in a porous material in which a liquid may be elevated or depressed when it comes in contact with the material [11].

The phenomenon which causes a rise or depression of spreading of liquid through the pores of free spaces of the fabric is called capillarity or capillary action or wicking [12].

Capillary action should not be confused with hygroscopic nature of a fibre. Hygroscopic fibres absorb water vapour from the moist atmosphere or liquid source but wicking is actually more like sucking liquid from liquid source with straw or anything like straw which would give free path. The capillary or wicking action is determined by effective capillary pore distribution, pathways and surface tension [20]. The wicking is also dependent on wetting of the fabric. This wetting is determined by the surface properties of the fibre and the wetting liquid. In case of human, the skin can be the source of liquid or more specifically sweat is the source of liquid. So when the sweat arrives above the skin, the sweat will be absorbed by hygroscopic fibre but the area of the fabric which absorbs the sweat depends on the wicking behaviour of the fibre and also the fabric [12].

Table 1: Samples.

Sample No.	Fabric Types	Stitch Length (mm)	Yarn Count	Raw Materials	GSM
1	Single Jersey	2.41	28	100% Cotton (Not Scoured)	159
2	Single Jersey	2.60	28	100% Cotton (Not Scoured)	148
3	Single Jersey	2.68	28	100% Cotton (Not Scoured)	145
4	Single Jersey	2.85	28	100% Cotton (Not Scoured)	142
5	Single Jersey	2.90	28	100% Cotton (Not Scoured)	140
6	1x1 Rib	2.60	28	100% Cotton (Not Scoured)	211
7	1x1 Rib	2.65	28	100% Cotton (Not Scoured)	200
8	1x1 Rib	2.75	28	100% Cotton (Not Scoured)	193
9	1x1 Rib	2.82	28	100% Cotton (Not Scoured)	185
10	1x1 Rib	2.90	28	100% Cotton (Not Scoured)	179

Capillary action takes place in all directions, not just in the vertical direction. So, water is drawn into the fibres of a fabric is irrespective of its orientation. The rate at which a pore fills is related to the pore size. The narrower capillaries will fill slowly but eventually will fill or rise more [13, 14]. So, the wicking rate depends on the free space or hollow space in yarn and also in the fabric[3. 15]. Actually the hollow means the free path between the fibres of the yarn and path between the yarns in the fabric. The wicking rate gets higher when the space increases in fabric which means comparatively loose structure may help wick-ability of the fabric. So fabric structure can be an important factor. And if the fibre can offer any straw like structure that will help to develop natural wick-ability in fabric. The fibre can play vital role in wicking behavior of the fabric too as some fibres can offer capillary structure through it. Cotton is the best example of fibre which can offer straw like hollow lumen in its structure. This phenomenon is actually measured from a submerged fabric sample in water or any other liquid where the liquid column rise with time needs to be measured and compared [16-18].For this test, principle of AATCC Test Method 197-2012 (Vertical Wicking Test) is to be used.

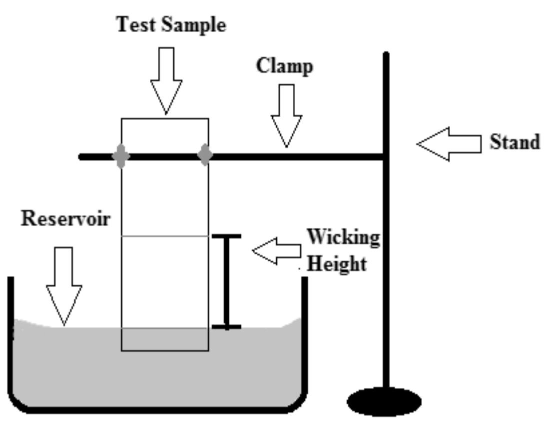

Figure 1: Wicking Test.

Procedure

- The samples were cut in dimension 2.5cm wide x 17cm long.
- Samples were conditioned in atmospheric condition.
- Samples were hung on a clamp with 1 cm of the samples was submerged in water.
- A measurement of how far the water has moved along upward with the capillary action of fabric. The test was run for five minutes, and then the length of the column of solution risen above from that submerged 1 cm was measured for all samples.
- The weight of the samples after 5 minutes can also indicate wick-ability of the samples.

Drying Rate Test

Drying rate indicates the time required to evaporate the absorbed or taken liquid to the surroundings. Better drying rate mean less time required to become dry. As mentioned before, drying rate depends on the amount of liquid absorbed by the material and also the ability of the material to desorb or evaporate the liquid. This depends on the type of raw material, the weight per square meter of the fabric, the fabric structure etc[19]. In case of raw material, a material with too high absorbency or too low absorbency, both should be avoided because the first would just try to retain water and stay wet which is undesirable and the later one would tend to take no water and let the human skin stay wet. In this case, man-made fibres can be helpful as it can offer more regular molecular orientation and cross section which helps dry-ability [20]. The wicking rate affects the drying property more from this point of view as it is easier to evaporate same amount of liquid from higher surface area than lower surface area. So, high wick-ability will help drying property [21]. By Fabric of higher GSM may absorb more water but with lower wick-ability, it will take more time to evaporate the water. But the fabric which can absorb reasonable amount and can dry itself quicker, that can be termed as a fabric with high drying rate. This drying rate can be determined by measuring the weight loss of fully wet fabric at specific intervals. For this test, principle of AATCC Test Method 201-2013(Drying Rate of Fabrics: Heated Plate Method) is to be used.

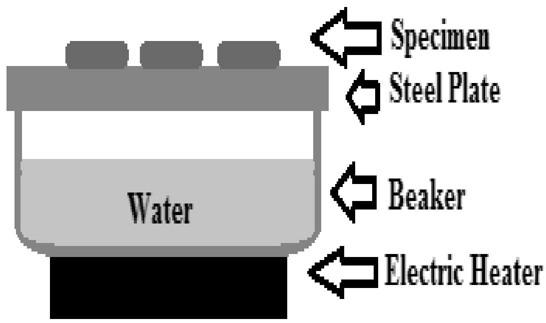

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Figure 2: Drying Rate Test.

Procedure

- The samples were cut in dimension 2.5cm wide× 17cm long.
- Samples were conditioned in atmospheric condition and weighed.
- Samples were immersed in water for long enough to wet the samples totally, then the samples were taken out of water and then weighed when the samples had the water up to 100% saturation level. This gave the weight of absorbed water by samples.
- The samples were placed on the steel plate which is heated by steam and as shown in the figure. The temperature of the plate was maintained around 37°C by controlling the temperature of the heater.
- Then the weights of the samples were taken after every 2 minutes for 7 times to find out drying rate per second or minute by measuring the water evaporation at intervals by the samples.

Results

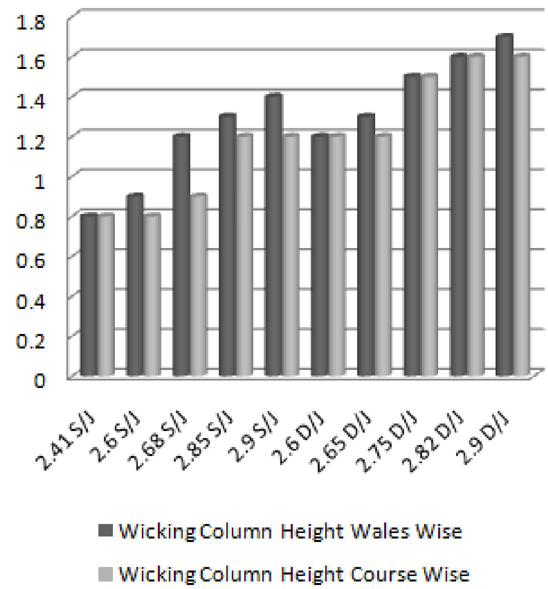

Figure 3: Wicking Height of samples.

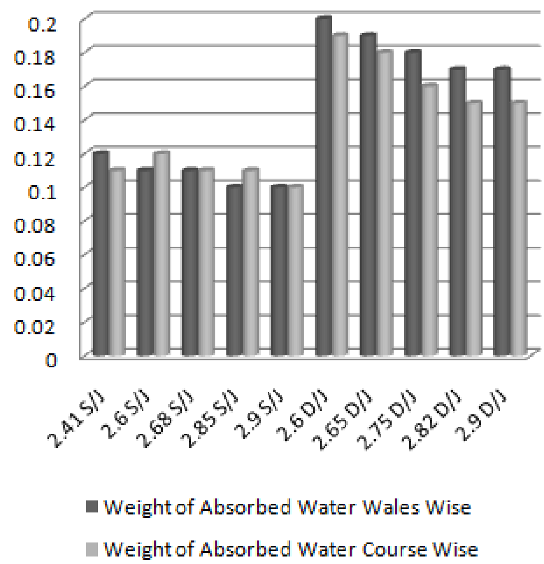

Figure 4: Absorbed Water by samples Due to Wicking.

Table 1: Wicking Test Results.

Sample		Samples in wales direction				Samples in course direction			
		Weight of Dry Samples gm	Weight of Submerged Samples gm	Difference in Weight gm	Height of Water Column cm	Weight of Dry Samples gm	Weight of Submerged Samples gm	Difference in Weight gm	Height of Water Column cm
Single Jersey Samples with stitch length in	2.41	0.70	0.82	0.12	0.8	0.69	0.80	0.11	0.8
	2.60	0.69	0.80	0.11	0.9	0.66	0.78	0.12	0.8
	2.68	0.66	0.77	0.11	1.2	0.66	0.77	0.11	0.9
	2.85	0.61	0.72	0.10	1.3	0.61	0.72	0.11	1.2
	2.90	0.60	0.70	0.10	1.4	0.61	0.71	0.10	1.2
Double Jersey Samples with stitch length in	2.60	0.85	1.05	0.20	1.2	0.84	1.01	0.19	1.2
	2.65	0.79	0.98	0.19	1.3	0.80	0.98	0.18	1.2
	2.75	0.78	0.96	0.18	1.5	0.76	0.92	0.16	1.5
	2.82	0.81	0.98	0.17	1.6	0.82	0.97	0.15	1.6
	2.90	0.76	0.93	0.17	1.7	0.78	0.93	0.15	1.6

Table 3: Drying Test Results

Sample			Weight of Dry Sample gm	Weight of Wet Sample gm	Weight of Sample after 2 minutes	Weight of Sample after 4 minutes	Weight of Sample after 6 minutes	Weight of Sample after 8 minutes	Weight of Sample after 10 minutes	Weight of Sample after12 minutes	Weight of Sample after 14 minutes	Water Evapora-tion rate Per min
S/J Samples with stitch length in mm	2.41	In Wales direction	0.70	1.27	1.17	1.09	1.01	0.94	0.88	0.83	0.79	0.03429
		In course direction	0.69	1.23	1.15	1.07	1.0	0.93	0.88	0.83	0.79	0.03143
	2.60	In Wales direction	0.69	1.25	1.14	1.04	0.96	0.89	0.83	0.77	0.73	0.03714
		In course direction	0.66	1.27	1.17	1.07	0.99	0.92	0.86	0.81	0.77	0.03571
	2.65	In Wales direction	0.66	1.29	1.18	1.07	0.98	0.90	0.81	0.77	0.73	0.04
		In course direction	0.66	1.26	1.15	1.04	0.97	0.90	0.83	0.78	0.75	0.03643
	2.85	In Wales direction	0.61	1.30	1.17	1.07	0.96	0.86	0.78	0.72	0.67	0.045
		In course direction	0.61	1.28	1.17	1.06	0.97	0.88	0.80	0.74	0.69	0.04214
	2.90	In Wales direction	0.60	1.31	1.17	1.05	0.94	0.86	0.77	0.70	0.65	0.04714
		In course direction	0.61	1.27	1.11	1.02	0.92	0.84	0.77	0.70	0.66	0.04357

D/J Samples with stitch length in mm	**2.60**	In Wales direction	0.85	2.19	1.79	1.51	1.26	1.11	1.03	0.95	0.88	0.09357
		In course direction	0.84	2.13	1.82	1.60	1.31	1.19	1.04	0.96	0.91	0.08714
	2.65	In Wales direction	0.79	2.27	1.91	1.69	1.38	1.12	0.98	0.90	0.86	0.10071
		In course direction	0.80	2.20	1.89	1.63	1.39	1.21	1.10	0.97	0.89	0.09357
	2.75	In Wales direction	0.78	2.34	1.94	1.61	1.38	1.22	1.10	0.90	0.83	0.10786
		In course direction	0.76	2.28	1.92	1.60	1.38	1.23	1.08	0.90	0.84	0.10286
	2.82	In Wales direction	0.81	2.41	1.94	1.66	1.42	1.24	1.00	0.89	0.83	0.11286
		In course direction	0.82	2.30	1.99	1.69	1.40	1.20	1.02	0.90	0.83	0.105
	2.90	In Wales direction	0.76	2.42	1.90	1.57	1.31	1.18	0.98	0.84	0.77	0.11786
		In course direction	0.78	2.35	1.88	1.45	1.25	1.10	0.99	0.85	0.80	0.11071

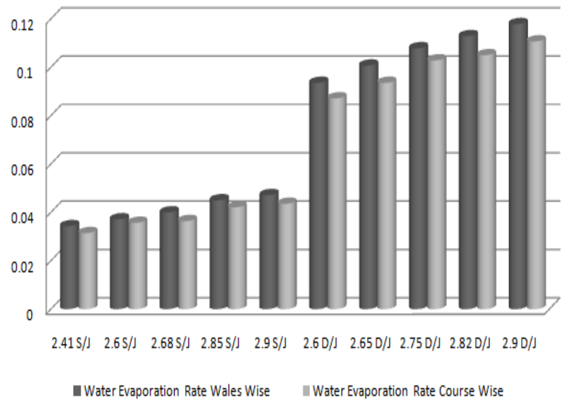

Figure 5: Drying Rate per Minute.

Discussion

Findings

The following trends have been found from the test results;

- From results given in table 2 and figure 3 and 4, it can be seen that, fabrics with higher stitch length have shown better wicking behavior. That's why an upward trend is seen when the results are shown in order of increasing stitch length.
- From results given in table 2 and figure 3 and 4, it can be seen that, samples cut in wales wise direction has shown better wick-ability than course wise samples and this trend is seen in both structures.
- From results given in table 3 and figure 5, it can be seen that, fabrics with high stich length has shown higher drying rate for both type of structure. Again, it is found higher in wales wise samples than course wise samples.
- From results given in table 2 and 3 and figure 3,4 and 5, it can be seen that, Rib structure has shown comparatively better wicking and drying behavior than Single Jersey Plain structure.

Explanation

- Stitch length affects the fabric tightness or looseness. When the stitch length is higher, the fabric becomes looser in construction. As it is already said before that, wick-ability is helped by looseness or free spaces in the fabric [3, 15], higher stitch length gives that free spaces in the structure. That's why the wicking rate is found higher when stitch length was increased.
- Samples cut in wales wise direction has shown higher wick-ability in most cases than samples of course direction. It means samples which has more wales in it than course has been found better in wicking test than samples containing more courses. It is because the wale per unit length of a fabric is generally less than courses per unit length in the same fabric. Again, samples cut in wales wise direction presents lesser number of loops to the water solution to travel through than samples cut in course wise direction. For example, the single jersey plain sample having 2.90 mm stitch length has 31 wales per inch and 60 courses per inch. When sample was cut in wales wise direction, it contained 30 wales per course and in total 400 courses. So when the sample was used in wicking test, it presented only 30 wales in direct contact with the water as the sample was submerged in water vertically. On the other hand, for same fabric, the course wise sample had 59 courses containing 207 wales per course. The total number of loops may not vary much, but in this case, 1 cm of 59 courses were submerged in water. Again, the samples cut in wales wise direction could offer the vertical loops to vertical wicking test but the other set presented the loops at sidewise direction. Since the lower number of wales or loops gave easier path to the water to travel through, the wick-ability were found higher for samples cut in wales wise direction.
- As said earlier, wicking helps drying of the fabric [21]. It is because, wicking actually helps spreading the absorbed water or any kind of liquid in a larger area of the fabric rather than just

containing the water in the area where it is dropped or got absorbed by the fabric from any source. That's why in wicking test, the water column rises through the fabric when only 1 cm of the fabric is submerged in water or liquid source. It was also seen in wickig test done here. So, high wick-ability actually helped the fabrics spread the absorbed water to a larger area [8] and it is well known that, water can evaporate from larger area easily than from small area. That's why if the same amount of water is contained in a bucket stays there all day but if it is spread on floor, it will evaporate after a while. The same principle worked for the samples. That's why when a sample had higher wick-ability, the drying rate was found higher too. That means samples with higher stitch length showed higher dry-ability. Another reason was, since the samples were not scoured, the absorbency of the cotton fabric was too low and it was all down to the wick-ability and free spaces of the samples to retain and distribute water through and in the free spaces of the fabric. It is also easier to evaporate water from outside the fibres rather than from inside the fibres. That's why the amount of water contained by samples were not varying much instead the looser samples almost matched the compact samples even though their GSM was a bit lower due to better ability to offer free spaces in the fabric. So from all points of view, the free path in fabrics can both help wick-ability and dry-ability of a fabric.

- Rib structure has been found aiding wick-ability and dry-ability more than single jersey plain structure. It is already said that wicking is a kind of capillary action. And in rib structure, the ribbed surface can offer rib lines or half of a capillary tube type path all over the fabric in wales direction. Since the capillary action can take place in both horizontal and vertical direction, the wicking rate was found higher for both wales wise and course wise samples than single jersey plain structure for same stitch length. The results show that too, as the single jersey plain sample of 2.90 mm had 1.4 cm and1.2 cm wicking height respectively for wales and course wise samples while for same stitch length, the wales and course wise wicking heights were found 1.7 cm and 1.6 cm. the drying rates were .047 and .044 gm per minute for single jersey fabric and .118 and .110 gm per minute for rib fabric for samples in both directions even though the rib fabircs took more water due to the higher GSM. Again, if samples were made of same GSM for both structures, the stitch length of rib fabric will have to be much higher which is certainly going to help wicking and drying. It is also said that, the fabrics should absorb less and transport more liquid to give comfort to the wearer[22], so fabrics with lower stitch length is going to be more helpful for rib structures. And since the ribbed effect helps wicking and drying, structures with thicker ribbed effect may be more helpful.

Conclusion

It was tried to find a quickly dry-able weft knitted fabric structure. Only plain and rib structures were used only as interlock and purl structures were ignored. The reasons behind the omission of these two structures were; interlock structure contains of two rib courses in every single course which makes the fabric more compact than rib. So the results can be assumed from results of rib structure. On the other hand purl structure contains technical face and back of plain structure alternately. So it is expected to show results just like or around the results of plain structure. Since the results have shown that, wick-ability and dry-ability are directly proportional to each other and comparatively loose fabric shows better wick-ability as well as dry-ability. So the interlock structure is not expected to be good in this case. Again the rib structure has been found as a structure of better wick-ability and quickly dry-able than plain structure. So, purl structure is also expected to follow results of plain structure. So it is clear that, using these two structures is enough to find out the quickly dry-able weft knitted fabric structure. Another factor found here is the stitch length as higher stitch length seems to aid wick-ability and dry-ability. It was also found that, the liquid can spread through courses and wales of a fabric but the rate is generally higher in wales wise direction. So in conclusion, it can be said that the rib structure can be used in fabrics worn in direct contact to the skin like underwear, sportswear etc which can give quick drying property to the fabric and make the wearer feel comfortable. And lower stitch length should be used as it will allow the liquid to go to outer surface of the fabric from inner surface of the fabric through the pores made by larger loops in the fabric and it will help keeping the skin dry. From here further research can be done to find a suitable combination of raw material of yarn and also the ratio of different raw materials which would help the dry-ability more. Some research has already been done which shows synthetic fibre more specifically hydrophobic fibres can aid wick-ability and dry-ability as mentioned earlier already.[7] But the totally hydrophobic nature may be a bit problematic and in that case some change in molecular structure or blending hydrophobic fibre with a bit of hydrophilic fibre may solve this problem.

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