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LABORATORY REPORT

Assessment of aerosol generation and spread by four different hand drying techniques, including the Dyson Airblade hand dryer

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PROJECT: FH/REP/103556/1

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BACKGROUND

Dyson are currently marketing their Airblade hand dryer to providers of public washroom facilities and now wish to expand their sales into the food manufacture and service industries. All hand drying techniques have the potential to generate bacterial aerosols. In a food production environment consideration must be given to the contribution the hand drying technique makes toward the bacterial contamination of food produced within the same area.

CCFRA have taken a number of inquiries from their members about the suitability of the Dyson Airblade hand dryer for use by operatives in food production environments. The food industry appreciates the critical value of hand hygiene practices with respect to food safety and are always trying to improve. When new products appear on the market it is thus essential that the industry fully understands their potential advantages/ disadvantages before decisions can be made on their suitability. Historically the food industry looks to CCFRA to help them make that judgment.

Consequently, Dyson approached CCFRA to design and conduct a series of experiments to help assess the production and spread of aerosols and particles by a range of hand drying techniques, including their Airblade hand dryer, under controlled laboratory conditions.

Aims

The aims of these investigations are to:

- Evaluate four different hand drying techniques - use of paper towels, use of a hot air hand dryer, use of an accelerated air hand dryer and use of the Dyson Airblade hand dryer, with regard to the generation and spread of water droplets (ballistic droplet travel, using water and absorbent paper), total aerosols (via air impaction sampling), gravimetrically deposited aerosols (via settle plates) and particle production (via a particle sampler)
- Compare the findings and comment on the suitability of the Dyson Airblade for use in food production environments.

Objectives

- To provide Dyson with a report containing the experimental protocols used, the results obtained and, based on those results, comment on the suitability of the Airblade for use in food production environments.

Following several meetings, held at CCFRA, between Toby Saville (Dyson), John Holah (CCFRA) and Debra Smith (CCFRA) the following experimental protocols were agreed:

METHOD

1. **Ballistic droplet generation and spread -** Dyson Airblade and accelerated air hand dryers only

   a. All experiments to be conducted in the controlled environment of Annex 1 in the Air Laboratory at CCFRA.
   b. Mount the Dyson Airblade hand dryer on a portable wooden back plate at the height stated by the manufacturers.
   c. Place the wooden back plate in the centre of the back wall of Annex 1 in the Air Laboratory.
   d. Cover the surrounding floor with absorbent blue paper.
   e. Draw a grid of 50cm x 50cm squares onto the absorbent blue paper.
   f. Dip hands in to a container of water and use the Dyson Airblade hand dryer as per manufacturers instructions, until the hands are dry.
   g. Assess the spread of any droplets produced during the hand drying event by circling the droplet marks left on the absorbent paper with a permanent marker.
   h. Repeat this process 15 times in total, with at least 5 different volunteers.
   i. Count and record the number of droplets per 50cm x 50cm square.
   j. Repeat the experiment using the accelerated air hand dryer.

2. **Gravimetric aerosol generation and spread -** All hand drying methods

   a. All experiments to be conducted in the controlled environment of Annex 1 in the Air Laboratory at CCFRA.
   b. Mount the Dyson Airblade hand dryer on a portable wooden back plate at the height stated by the manufacturers.
   c. Place the wooden back plate in the centre of the back wall of Annex 1 in the Air Laboratory.
   d. 'Clean' the air in the Air Laboratory using a HEPA air filtration system (Microflow Ltd.) at this points and others marked by * for ~ 1-2 hours. Verify the cleaning using a particle counter (Lasair II) for 1 minute, <100 particles = clean
   e. Place 22 x Nutrient agar (NA, Oxoid: CM3) filled settle plates (Appletonwoods 90mm petri dishes, product code: P903) on the Annex floor at marked distances from the Dyson Airblade hand dryer (see Figure 3, Appendix 1 for plate positions).
   f. Have 5 different volunteers enter the Annex one after the other and go through the motions of using the Dyson Airblade hand dryer as per manufacturers instructions for the same amount of time it took to dry the hands.
   g. Leave the settle plates exposed for a total of 1 hour then remove and incubate at $30^{o}C \pm 1^{o}C$ for ~ 48 hours (= background gravimetric aerosol counts).
   h. * ~ 1-2 hours.
   i. Place new NA settle plates at marked distances from the Dyson Airblade hand dryer.

j. Have 5 different volunteers wash their hands in the Air Laboratory and then enter Annex 1 to use Dyson Airblade hand dryer as per manufacturers instructions until the hands are dry.
k. Leave the settle plates exposed for a total of 1 hour then remove incubate at 30^{o}C ± 1^{o}C for ~48 hours (= gravimetric aerosol counts generated by Dyson Airblade hand dryer).
l. Repeat this experiment 3 times in total on separate occasions.
m. Repeat this experiment using paper towels, the hot air hand dryer and the accelerated air hand dryer.

3. <u>Total aerosol generation</u> - All hand drying methods

a. All experiments to be conducted in the controlled environment of Annex 1 in the Air Laboratory at CCFRA.
b. Mount the Dyson Airblade hand dryer on a portable wooden back plate at the height stated by the manufacturers.
c. Place the wooden back plate in the centre of the back wall of Annex 1 in the Air Laboratory.
d. Install 2 large volume air impaction samplers (Oxoid: MAQS II & MAQS), one close to the Airblade (MAQS II-80cm high and 30cm to the left) and the other at the furthest point from it (MAQS - 25.5cm high and 2m in front).
e. 'Clean' the air in the Air Laboratory using a HEPA air filtration system at this point and others marked by * for ~ 1-2 hours. Verify the cleaning using a particle counter for 1 minute, <100 particles = clean.
f. Fit each air sampler with 90 mm diameter NA filled plate.
g. Have 5 different volunteers enter the Annex one after the other and <u>go through the motions of</u> using the Dyson Airblade hand dryer as per manufacturers instructions for the same amount of time as it took to dry the hands.
h. The last volunteer to leave the room must switch on the air sampler on to run for 100 seconds to draw in 200 litres of air at 2 litres/sec.
i. Remove the NA plates from the air sampler and incubate at 30^{o}C ± 1^{o}C for ~ 48 hours (= background total aerosol counts).
j. * ~ 1-2 hours.
k. Fit each air sampler with a fresh NA plate.
l. Have 5 different volunteers wash their hands in Air Laboratory and then enter Annex 1 to use Dyson Airblade hand dryer as per manufacturers instructions until the hands are dry.
m. The last volunteer to leave the room must switch on the air sampler on to run for 100 seconds to draw in 200 litres of air at 2 litres/sec.
n. Remove the NA plates from the air sampler and incubate at 30^{o}C ± 1^{o}C for ~ 48 hours (= total aerosol counts generated by Dyson Airblade hand dryer).
o. Repeat this experiment 3 times in total on separate occasions.
p. Repeat this experiment using paper towels, the hot air hand dryer and the accelerated air hand dryer.

4. Particle generation - <u>All hand drying methods</u>

a. All experiments to be conducted in the controlled environment of Annex 1 in the Air Laboratory at CCFRA.
b. Mount the Dyson Airblade hand dryer on a portable wooden back plate at the height stated by the manufacturers.
c. Place the wooden back plate in the centre of the back wall of Annex 1in the Air Laboratory.
d. Install the particle sampler (Lasair II) in Annex 1.
e. Clean the air in the Air Laboratory using a HEPA air filtration system at this point and others marked by * for ~ 1-2 hours. Verify the cleaning using a particle counter for 1 minute, <100 particles = clean
f. Have 5 different volunteers, wearing one piece, head to toe covering paper suits (Pro-Tech overalls, product code: 11012172), enter the Annex, one after the other and <u>go through the motions of</u> using the Dyson Airblade hand dryer, as per manufacturers instructions, for the same amount of time as it took to dry the hands.
g. Turn particle sampler on to run for 1 minute and record the number and size of particles generated (= background particle counts).
h. * ~ 1-2 hours
i. Have 5 different volunteers, wearing one piece, head to toe covering paper suits wash their hands in Air Laboratory and then enter Annex 1 to use the Dyson Airblade hand dryer, as per manufacturers instructions, until the hands are dry.
j. Turn the particle sampler on for 1 minute and record the number and size of particles generated (= particle counts generated by Dyson Airblade hand dryer).
k. Repeat this experiment 3 times in total on separate occasions.
l. Repeat this experiment using paper towels, the hot air hand dryer and the accelerated air hand dryer.

Note: Clean paper suits were worn for each different dryer type.

RESULTS

Experiment 1

Figures 1 & 2 in Appendix 1 show the locations and number of ballistic droplets produced by the Dyson Airblade and accelerated air hand dryers, respectively.

Table 1: Ballistic droplet production by Dyson Airblade and accelerated air hand dryers

	Droplet numbers	
Droplet location (please refer to Figures 1 & 2)	**Dyson Airblade**	**Accelerated Air**
A1	97	0
A2	217	33
A3	340	352
A4	266	1235
A5	216	1021
A6	278	362
A7	235	25
A8	181	0
B1	14	1
B2	48	32
B3	134	206
B4	165	253
B5	77	175
B6	133	82
B7	110	4
B8	107	0
C1	2	0
C2	2	1
C3	57	4
C4	10	10
C5	1	4
C6	20	4
C7	19	0
C8	20	0
D1	0	0
D2	0	0
D3	3	1
D4	1	1
D5	1	1
D6	0	0
D7	1	0
D8	0	0
E1	0	0
E2	0	0
E3	1	3
E4	0	5
E5	1	1
E6	0	0
E7	1	0
E8	0	0

Experiment 2

Tables 2 to 5 show the results of the 1 hour settle plate aerosol counts for the Dyson Airblade, the hot air dryer, the accelerated air dryer and the paper towel hand drying methods.

Table 2: Dyson Airblade aerosol counts (1 hour settle plates)

Experiment number	Plate position code (please refer to Figure 3)	Background count (cfu/90 mm diam plate)	Test count (cfu/90 mm diam plate)
1	A1	6	26
	A2	3	13
	A3	0	9
	B1	6	8
	B2	2	7
	B3	6	5
	C1	6	14
	C2	Contaminated	7
	D1	5	4
	E1	Contaminated	3
	E2	8	7
	F1	6	9
	F2	5	4
	G1	6	4
	H1	5	4
	H2	3	7
	I1	1	10
	I2	4	7
	I3	5	3
	J1	8	5
	J2	7	7
	J3	0	6
	MEAN	***5**	**8**
2	A1	1	2
	A2	0	0
	A3	0	1
	B1	0	1
	B2	0	1
	B3	1	1
	C1	0	2
	C2	0	0
	D1	2	Contaminated
	E1	0	0
	E2	1	0
	F1	1	Contaminated
	F2	0	1
	G1	1	0
	H1	0	2
	H2	0	1
	I1	0	6

Table 2 (cont.): Dyson Airblade aerosol counts (1 hour settle plates)

Experiment number	Plate position code (please refer to Figure 3)	Background count (cfu/90 mm diam plate)	Test count (cfu/90 mm diam plate)
	I2	0	1
	I3	0	0
	J1	0	26
	J2	0	5
	J3	1	10
	MEAN	**0**	***3**
3	A1	3	10
	A2	10	12
	A3	1	7
	B1	4	7
	B2	4	7
	B3	11	6
	C1	6	7
	C2	7	3
	D1	9	4
	E1	5	5
	E2	6	7
	F1	5	4
	F2	5	Contaminated
	G1	5	6
	H1	7	3
	H2	2	7
	I1	9	1
	I2	5	6
	I3	3	2
	J1	4	13
	J2	6	9
	J3	2	5
	MEAN	**5**	***6**
	OVERALL MEAN	***4**	***6**

cfu – colony forming units
*Based on available counts

Table 3: Hot air hand dryer aerosol counts (1 hour settle plates)

Experiment number	Plate position code (please refer to Figure 3)	Background count (cfu/90 mm diam plate)	Test count (cfu/90 mm diam plate)
1	A1	2	26
	A2	0	11
	A3	3	13
	B1	6	16
	B2	2	7
	B3	1	9
	C1	5	6
	C2	6	3
	D1	15	10
	E1	5	15
	E2	8	13
	F1	6	10
	F2	0	Contaminated
	G1	3	5
	H1	1	16
	H2	7	10
	I1	4	11
	I2	2	Contaminated
	I3	4	Contaminated
	J1	2	15
	J2	2	11
	J3	2	8
	MEAN	**4**	***11**
2	A1	Contaminated	50
	A2	Contaminated	12
	A3	4	8
	B1	2	22
	B2	6	11
	B3	8	3
	C1	10	11
	C2	4	5
	D1	10	8
	E1	Contaminated	15
	E2	7	6
	F1	7	Contaminated
	F2	4	Contaminated
	G1	6	Contaminated
	H1	8	Contaminated
	H2	4	6
	I1	4	14
	I2	3	3
	I3	6	11
	J1	3	Contaminated
	J2	4	3
	J3	9	9
	MEAN	***6**	***12**

Table 3 (cont.): Hot air hand dryer aerosol counts (1 hour settle plates)

Experiment number	Plate position code (please refer to Figure 3)	Background count (cfu/90 mm diam plate)	Test count (cfu/90 mm diam plate)
3	A1	6	23
	A2	5	17
	A3	2	9
	B1	Contaminated	31
	B2	9	9
	B3	3	2
	C1	1	21
	C2	0	6
	D1	1	12
	E1	1	25
	E2	0	9
	F1	1	13
	F2	0	9
	G1	0	13
	H1	6	26
	H2	6	9
	I1	8	20
	I2	10	12
	I3	1	5
	J1	2	29
	J2	4	14
	J3	1	6
	MEAN	***3**	**15**
	OVERALL MEAN	***4**	***13**

cfu – colony forming units
*Based on available counts

Table 4: Accelerated air hand dryer aerosol counts (1 hour settle plates)

Experiment number	Plate position code (please refer to Figure 3)	Background count (cfu/90 mm diam plate)	Test count (cfu/90 mm diam plate)
1	A1	23	>300
	A2	18	111
	A3	14	70
	B1	13	172
	B2	21	80
	B3	13	62
	C1	25	156
	C2	Contaminated	60
	D1	24	96
	E1	20	146
	E2	23	98
	F1	22	142
	F2	17	96
	G1	21	90
	H1	19	200
	H2	13	75
	I1	14	>300
	I2	16	130
	I3	12	89
	J1	12	>300
	J2	15	188
	J3	29	262
	MEAN	***18**	****147**
2	A1	10	>300
	A2	7	127
	A3	2	63
	B1	4	158
	B2	4	55
	B3	4	Contaminated
	C1	Contaminated	124
	C2	Contaminated	48
	D1	5	60
	E1	Contaminated	84
	E2	Contaminated	54
	F1	6	109
	F2	5	65
	G1	5	96
	H1	Contaminated	113
	H2	8	70
	I1	Contaminated	156
	I2	18	88
	I3	Contaminated	73
	J1	6	>300
	J2	10	128
	J3	7	77
	MEAN	***7**	***/**112**

Table 4 (cont.): Accelerated air hand dryer counts (1 hour settle plates)

Experiment number	Plate position code (please refer to Figure 3)	Background count (cfu/90 mm diam plate)	Test count (cfu/90 mm diam plate)
3	A1	7	274
	A2	11	57
	A3	10	28
	B1	48	106
	B2	8	51
	B3	12	33
	C1	11	48
	C2	8	33
	D1	8	43
	E1	16	81
	E2	40	67
	F1	19	76
	F2	12	41
	G1	9	50
	H1	10	93
	H2	6	39
	I1	21	118
	I2	16	51
	I3	21	42
	J1	7	>300
	J2	8	118
	J3	10	59
	MEAN	**15**	****82**
	OVERALL MEAN	***13**	****114**

cfu – colony forming units
*Based on available counts
** Based on taking >300 counts as 300

Table 5: Paper towel aerosol counts (1 hour settle plates)

Experiment number	Plate position code (please refer to Figure 3)	Background count (cfu/90 mm diam plate)	Test count (cfu/90 mm diam plate)
1	A1	0	6
	A2	5	5
	A3	4	3
	B1	5	6
	B2	5	11
	B3	6	4
	C1	9	10
	C2	0	1
	D1	4	2
	E1	9	6
	E2	7	10
	F1	6	Contaminated
	F2	5	7
	G1	8	8
	H1	4	3
	H2	5	12
	I1	2	5
	I2	11	9
	I3	5	4
	J1	3	5
	J2	0	3
	J3	10	3
	MEAN	**5**	***6**
2	A1	7	9
	A2	3	Contaminated
	A3	1	6
	B1	8	15
	B2	6	9
	B3	10	8
	C1	11	12
	C2	9	3
	D1	7	6
	E1	4	6
	E2	13	8
	F1	5	3
	F2	6	6
	G1	5	Contaminated
	H1	5	3
	H2	4	4
	I1	6	7
	I2	10	8
	I3	7	5
	J1	7	5
	J2	5	7
	J3	7	1
	MEAN	**7**	***7**

Table 5 (cont.): Paper towel aerosol counts (1 hour settle plates)

Experiment number	Plate position code (please refer to Figure 3)	Background count (cfu/90 mm diam plate)	Test count (cfu/90 mm diam plate)
3	A1	5	3
	A2	4	7
	A3	5	4
	B1	8	8
	B2	10	11
	B3	7	8
	C1	11	10
	C2	8	4
	D1	14	6
	E1	8	8
	E2	10	13
	F1	5	9
	F2	10	6
	G1	6	6
	H1	7	16
	H2	5	4
	I1	9	7
	I2	13	7
	I3	3	6
	J1	8	7
	J2	8	6
	J3	7	9
	MEAN	**8**	**8**
	OVERALL MEAN	**7**	***7**

cfu – colony forming units
*Based on available counts

Experiment 3

Table 6: Air impaction sample results for four different types of hand drying methods

Hand Dryer	Experiment Number	Background count (cfu/90 mm diam plate/200 litres air)		Test count (cfu/90 mm diam plate/200 litres air)	
		Side	Back	Side	Back
Dyson Airblade	1	27	26	40	25
	2	17	19	28	29
	3	21	22	38	24
	Mean	**22**	**22**	**35**	**26**
Accelerated Air	1	26	30	135	90
	2	42	36	77	47
	3	34	13	84	29
	Mean	**34**	**26**	**99**	**55**
Hot Air	1	29	28	27	23
	2	22	36	19	19
	3	16	1	21	13
	Mean	**22**	**22**	**22**	**18**
Paper Towels	1	11	15	9	7
	2	33	24	14	14
	3	17	19	9	17
	Mean	**20**	**19**	**11**	**13**

Experiment 4

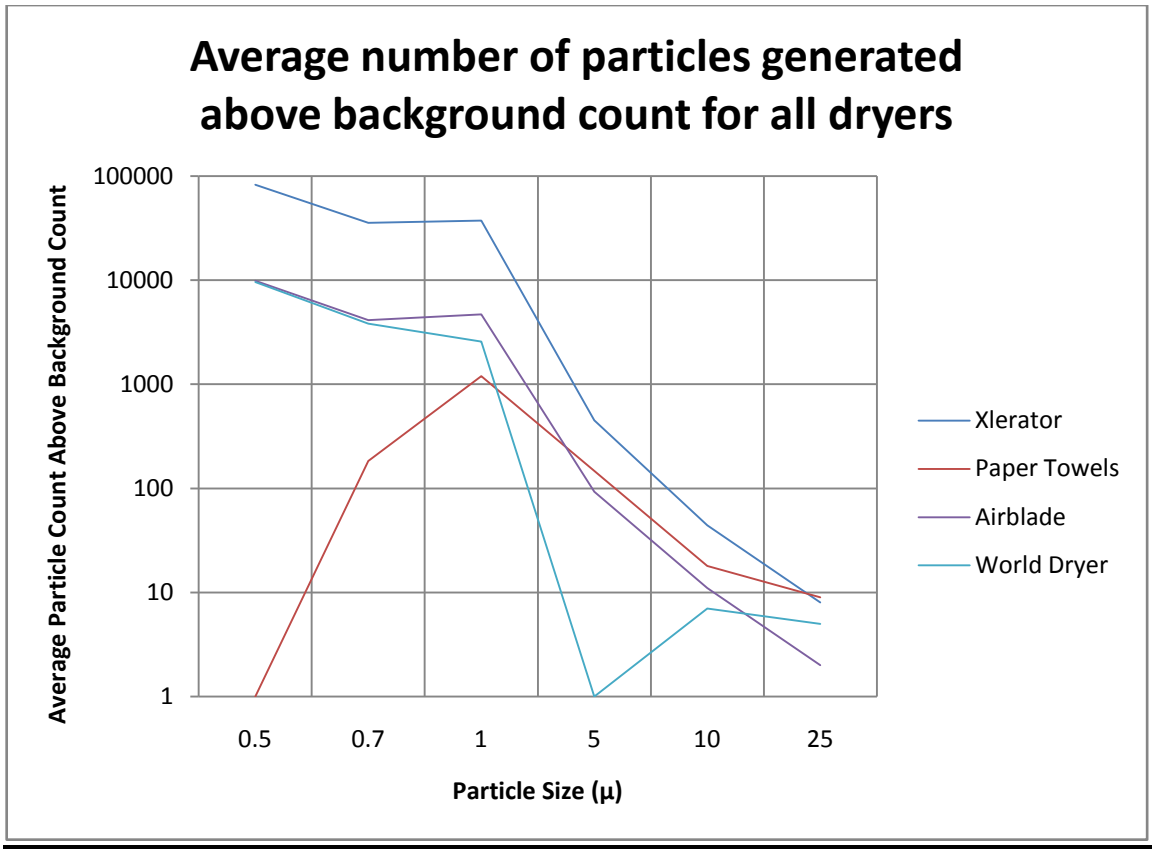
Table 7 and Graph 1 show the comparisons of average particle generation for the accelerated air hand dryer, the hot air hand dryer, the Dyson Airblade and paper towels.

Table 7: Comparisons of particle generations

Dryer	Particle size	Average Net Particle Generation (background counts) n=3	Average Net Particle Generation (test counts) n=3	Average Number of Particles Generated Above Background
Accelerated air	0.5	1292	83977	82685
	0.7	661	36246	35586
	1	2101	39574	37473
	5	194	642	449
	10	21	65	44
	25	2	10	8
Hot air	0.5	2969	12571	9602
	0.7	1376	5199	3823
	1	3455	6029	2575
	5	364	223	0*
	10	33	41	7
	25	2	7	5
Paper Towels	0.5	4528	4142	0*
	0.7	1561	1745	184
	1	2562	3761	1199
	5	247	394	147
	10	31	49	18
	25	1	10	9
Dyson Airblade	0.5	1743	11588	9845
	0.7	1051	5165	4114
	1	2594	7286	4692
	5	257	350	93
	10	29	40	11
	25	1	3	2

* negative results reported as 0 to allow graphing of data

Graph 1



DISCUSSION & CONCLUSIONS

Ballistic droplet generation (Experiment 1) dictates that the Dyson Airblade hand dryer should be situated at least 2.5 metres away from any food-contact or other hygiene-critical surface when located in a food manufacturing or preparation environment.

There were no practical differences between the use of the Dyson Airblade, the hot air hand dryer and the paper towels with regard to microbial aerosol generation (Experiments 2 and 3). The very low numbers of airborne microbes that were generated by each of these hand drying methods would make an insignificant contribution to the overall background microbial loading of the air in any food processing environment. However, the accelerated air dryer generated notably higher levels of microbial aerosols above both background and the other drying methods investigated.

With respect to particle counts (Experiment 4) use of the accelerated air hand dryer resulted in the greatest increase in airborne particles. Particle counts for the Dyson Airblade and the hot air hand dryer were comparable and those for the paper towels were the lowest.

CCFRA can conclude from the studies undertaken that the Dyson Airblade hand dryer appears to be suitable for use in food production environments with regard to microbial aerosol and particle generation and spread. These studies indicate that its use would

make an insignificant contribution to the microbial loading of background air. However, this conclusion should not be seen as an endorsement by CCFRA of any particular hand drying system.

Appendix 1