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Report

Testing and Evaluating Aerosol Sunscreens

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Table of Contents

Executive Summary 2

Acknowledgements 4

Introduction 5

Methods 7

- Synopsis 7
- Study Design 8
- Figure 1. Flow chart of testing procedures. 8
- Degassing protocol 9
- Figure 2. Degassing of Aerosol Sunscreens. 9
- Flow Rate determination protocol 9
- Figure 3. The actuator device. 10
- Figure 4. The flow rate experiment. 10
- Determining the length of time each Aerosol Sunscreen Product can be sprayed before the product is empty. 11
- Figure 5. The experiment to determine the length of time each product can be sprayed. 11

Results 12

- Sunscreen characteristics 12
- Figure 6. Aerosol Sunscreen Products tested. 12
- Table 1. Characteristics of Aerosol Sunscreen Products tested. 13
- Determining the amount of Propellant in each Aerosol Sunscreen Product 14
- Table 2. The amount of Propellant in each Aerosol Sunscreen product. 14
- Figure 7. Observations during the degassing process for the Surf Life Saving® Aerosol Sunscreen Product. 15
- Determining the Flow Rate and Sunscreen Coverage of each Aerosol Sunscreen Product. 16
- Table 3. Flow Rate determination for a 10 second duration of spray. 16
- Figure 8. Observations during the flow rate protocol for the Surf Life Saving® Aerosol Sunscreen Product. 17
- Determining the length of time each Aerosol Sunscreen Product can be sprayed and the flow rate produced over the course of spraying the entire contents of each product. 17
- Table 4. The length of time each Aerosol Sunscreen Product can be sprayed, and the flow rate produced over the course of spraying the entire product. 18
- Figure 9. Observations from the experiment spraying the entire product. 19

Reference List 20

Appendix 21

- Multimedia File 1. The degassing protocol for the Surf Life Saving® Aerosol Sunscreen Product. 21
- Multimedia File 2-4. The flow rate determination procedure of Aerosol Sunscreen Products. 21
- Multimedia File 5-14. The length of time for a new product to be sprayed before the Aerosol Sunscreen Product was empty 21

Executive Summary

Nine commercially available aerosol sunscreen products underwent testing to assess the amount of propellent contained in each product. Flow rate experiments were also undertaken to determine how long each product needed to be sprayed to reach an adequate coverage of sunscreen. Several companies had multiple aerosol products available, which were unique formulations and were included in the testing. Two Neutrogena® products and four Banana Boat® aerosol products were tested while one product from the brands Hawaiian Tropic®, Surf Life Saving® and Woolworths® were tested.

The proportion of propellant in aerosol sunscreens varied between products and ranged from 27%-83%. The Banana Boat® range consistently contained around 30% propellant in the four products tested, while the two Neutrogena® products tested contained 60% and 38% propellant respectively. During the degassing procedure, the Surf Life Saving® aerosol product was observed to undergo a process of gas escaping for the first minute of the procedure and then a bubbling foam was observed and 83% of the product escaped. This characteristic was observed in all three Surf Life Saving® aerosol products tested.

The flow rate was determined for each aerosol sunscreen product by dispersing sunscreen using a calibrated down-force actuator device, which was pressed for 10 seconds and the subsequent output collected. The flow rate data was used to calculate the time required to spray a product and achieve adequate coverage including 5 g per limb and 35 g for a whole body. The spray time required to provide adequate coverage varied greatly between the aerosol sunscreen products tested and ranged from 4 -14 seconds per limb. The four Banana Boat® products tested varied ranging from 9 -14 seconds per limb. The two Neutrogena® products tested also varied ranging from 6-13 seconds per limb. The Surf Life Saving® product reported the shortest spray time, however a thick foam was generated with a similar consistency to shaving foam and the ability for this foam to form a film of sunscreen on the skin is unknown. The Woolworths® aerosol product had the longest spray time requiring 14 seconds for a limb and 98 seconds for a whole body.

The total duration of time required to spray a product until it was empty ranged from 3 minutes to over 7 minutes. The four Banana Boat® products tested ranged from 5 minutes to 7 minutes. The two Neutrogena® products tested were similar with both products total spray time over 3 minutes. The Surf Life Saving® product reported the shortest total spray time 190 seconds and again a thick foam lotion was dispensed from this product. A flow rate calculation was performed using the duration to spray the entire product and the weight of the total product dispensed, which was used to estimate how many applications to an adult body (35 g) one product could provide. The two Neutrogena® products as well as the Woolworths® product could adequately cover 2 people. While one aerosol product could adequately cover 3 people for the Banana Boat®, Hawaiian Tropic® and Surf Life Saving® brands.

Whilst this study investigated the proportion of propellent in aerosol sunscreen products as well as the flow rate of sunscreen dispensed from commercially available products there is still further study required to answer additional questions on the efficacy and safety of these products. Extending the findings from this study to assess the impacts of environmental conditions, sunscreen formulation and nozzle geometry would be essential future research. Further experimental studies are also needed to provide detailed characterization of aerosol sunscreen and the deposition behaviour of these products on human skin. Experiments charactering the deposition behaviour of aerosol sunscreen products and testing how well a sun protection film can be achieved warrants further investigation. The inhalation risk from aerosol sunscreen products is another area requiring further research and studies determining the particle size dispensed from the consumer container would be essential.

Acknowledgements

This report was prepared by the Queensland University of Technology, with advice and assistance from the Victorian Cancer Council and the Australian Radiation Protection and Nuclear Safety Agency.

Introduction

Skin cancer is Australia's national cancer and was estimated to account for more cases diagnosed than all other cancers combined, which creates a significant public health burden (1). Diagnosis and management of skin cancer places a large burden on the health care system with the annual cost of a melanoma diagnosis estimated to be between $1,681 to $115,109 (AUD) per person per year, depending on if the melanoma is detected early (2). Keratinocyte skin cancers, while not always reported to cancer registries, have very high incidence rates in Australia (1,170 per 100,000) and were estimated to cost $703 million to diagnose and treat in 2015 (excluding out-of-pocket or societal costs) (3). Frequent exposure to high levels of ultraviolet (UV) radiation or sunlight is a key risk factor for developing melanoma and keratinocyte skin cancers and sunburn is an immediate indicator that sun damage has occurred.

Sunburn remains highly prevalent in Australia in the younger age groups and as little as one severe sunburn in childhood can double the risk of developing a melanoma before the age of 40 (4, 5). Daily sunscreen use at a population level has been shown to prevent keratinocyte cancers, melanoma deaths and to reduce healthcare costs (6). Molecular research has also shown the protective role for sunscreen when applied at the correct concentration of 2mg/cm^2, which blocked the harmful molecular effects of UV radiation(7). However, effectiveness of sunscreen depends on its application at an appropriate thickness (2mg/cm^2) and regular re-application (8). Previous research has shown both adults and children apply far less sunscreen than is recommended, which results in providing less protection (9, 10). An estimated 7220 melanoma cases could be prevented in Australia with effective use of sunscreen, however current sunscreen use has only reduced melanoma incidence by 1729 cases or 14%, illustrating there is substantial opportunity for improvement (11).

Public health campaigns have been communicating how much sunscreen is needed for adequate coverage, such as a teaspoon of lotion per limb. Aerosol sunscreens have been a recent addition to the sunscreen market, gaining popularity due to their novel and convenient application system. However, there has been limited advice or recommendations for the applications of aerosol sunscreen products with instructions on the label stating, "to use liberally". Aerosol sunscreen products can also be difficult

to see on the skin when applied, which could lead to areas being missed and there have been reports of serious sunburn incidents following use of aerosol sunscreens.

During 2018, the Therapeutic Goods Association (TGA) reported the findings from a compliance review of sunscreens, which showed the amount of product delivered per second varied between brands of aerosol sunscreens and the sun protection factor (SPF) claims were compliant with the current standard (12). However, the SPF testing is conducted on the sunscreen formulation and does not have the propellant added, which may lead to a more dilute sunscreen than an equivalent volume found in a sunscreen lotion (12). The TGA reports that consumers may have to use a greater amount of an aerosol sunscreen compared to a lotion or cream to achieve the same coverage and consumers must account for inter-brand variations by applying the product liberally to achieve adequate coverage (12).

In this study, we report the results from testing nine aerosol sunscreen products, which were commercially available in Australia during 2020.

Methods

Synopsis

Study Title	Testing and Evaluating Aerosol Sunscreens
Investigators	Dr Elke Hacker
Study site (s)	Queensland University of Technology, 60 Musk Avenue, Kelvin Grove
Study Design	Laboratory Testing
Planned Sample Size	Nine Aerosol Sunscreens
Study Period	**Aug 2020-Sep 2020**
Primary Objectives	The aim of this research project is to: i) assess the amount of propellent contained in each aerosol sunscreen and ii) determine how long each aerosol sunscreen needs to be sprayed to attain an adequate coverage of sunscreen
Main Inclusion criteria	• Aerosol sunscreen product commercially available in Australia.
Exclusion criteria	None
Test Product	• Neutrogena®: Ultra Sheer Body Mist Sunscreen • Neutrogena®: Beach Defence Sunscreen Spray • Banana Boat®: Simply Protect Kids Spray • Banana Boat®: Sport Cool Zone Spray • Banana Boat®: Ultra Clear Spray • Banana Boat®: Dry Balance Clear Spray • Hawaiian Tropic®: Tropic Silk Hydration Sunscreen Spray • Surf Life Saving®: Sunscreen Sport Spray • Woolworths®: Sunscreen Spray Everyday
Sponsor	Cancer Council Victoria
Partners	Australian Radiation Protection and Nuclear Safety Agency

Study Design

Nine commercially available aerosol sunscreen products underwent testing to assess the amount of propellent as well as sunscreen contained in each product (Figure 1). Flow rate experiments were also undertaken to determine how long each product needed to be sprayed to reach an adequate coverage of sunscreen (Figure1). The length of time for each product to be sprayed before the product was empty was also determined (Figure 1).

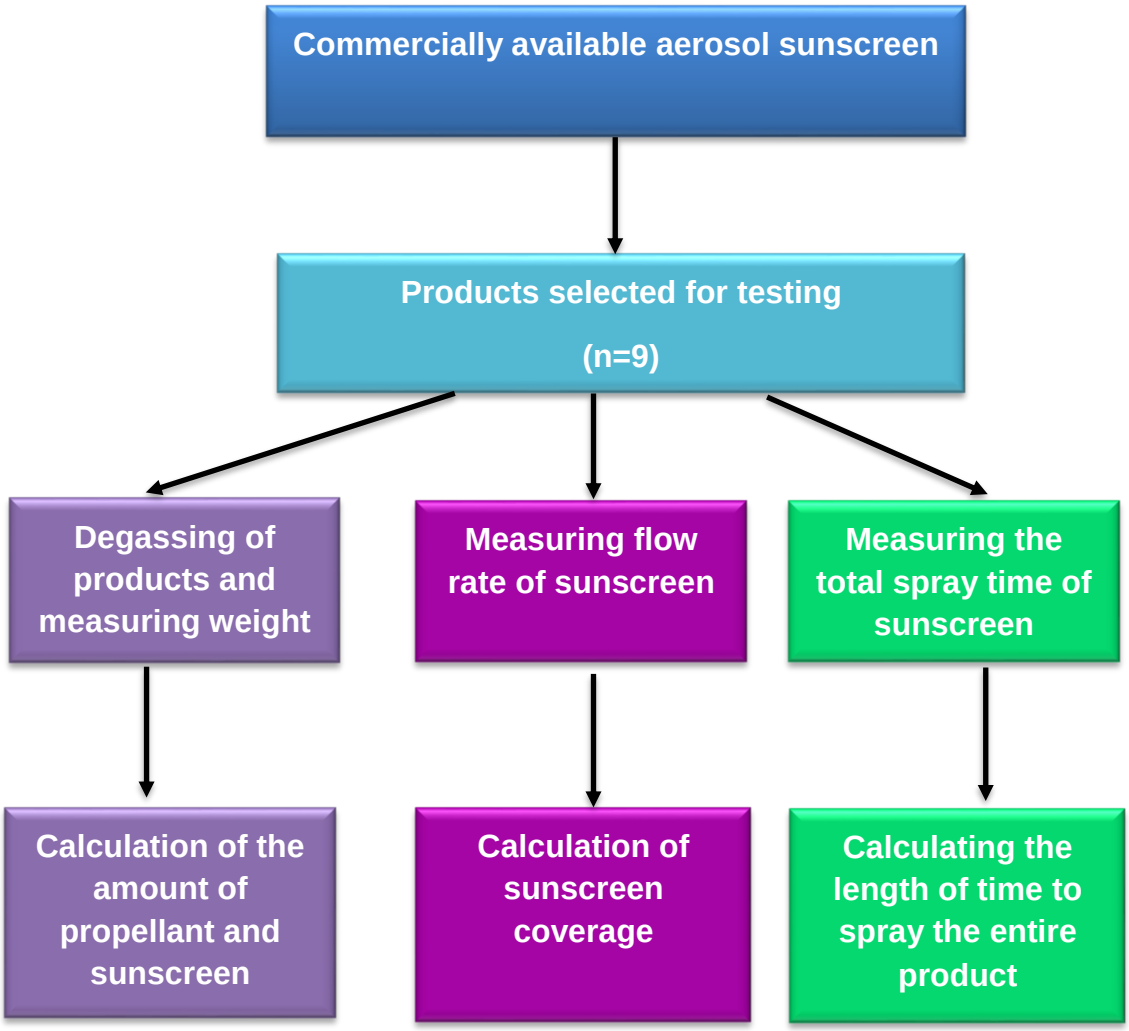

Figure 1. Flow chart of testing procedures.

Degassing protocol

The aerosol sunscreen products were degassed in accordance with the ISO 24443 standard. Briefly, a pin hole is made in the pressurized container and gas escapes to determine the weight of the propellent (Figure 2). The aerosol sunscreen products were weighed before any testing and 24 hours following the degassing process to assess the propellent component of each product. The weight before degassing minus the weight post 24 hours is used to calculate the weight of the propellent. Each of the nine sunscreen products were tested in triplicate.

Figure 2. Degassing of Aerosol Sunscreens. Left panel, a pin hole is made to the pressurized can for the propellent gas to escape. Right panel, the pin hole allows propellent gas to escape and the liquid sunscreen remains in the container.

Flow Rate determination protocol

Data collection was undertaken in a laboratory with a room temperature of 25 ^{0}C. The downforce actuator device used a horizontal toggle clamp to apply downforce on the aerosol sunscreen bottles (Figure 3). Custom bases were constructed for each product to ensure all products were placed in the actuator device at the same height. The toggle clamp was calibrated to 14.4N using a handheld Digital Force Gage (DILLON GL, China). The down force used was equivalent to the force used by a finger to

disperse sunscreen. A jet-spray of sunscreen was dispersed from all products using the actuator device (Figure 3).

Figure 3. The actuator device. The calibrated actuator device dispersing a jet-spray of sunscreen onto an arm 10cm away from the bottle.

The flow rate was determined for each aerosol sunscreen product by dispersing sunscreen using the actuator, which was pressed for 10 seconds and the subsequent output collected into a flask (Figure 4). The flask was weighed before testing and 1 hour following testing, which allowed for the propellent to evaporate. The flow rate was calculated for each product and completed in triplicate.

Figure 4. The flow rate experiment. The actuator device dispersed sunscreen from the aerosol sunscreen product into a collection flask.

Determining the length of time each Aerosol Sunscreen Product can be sprayed before the product is empty.

Data collection was undertaken in a laboratory with a room temperature of 25 ^{0}C. The actuator device was used to dispense each aerosol sunscreen product and a 2-litre glass flask was used to collect the output solution (Figure 5). A jet-spray of sunscreen was dispersed from all products continually until the bottle was empty, and the time taken was measured in seconds. The flask was weighed before testing and 1 hour following testing, which allowed for the propellent to evaporate.

Figure 5. The experiment to determine the length of time each product can be sprayed. The actuator device dispersed sunscreen from the aerosol sunscreen product into a large collection flask until the sunscreen bottle was empty.

Results

Sunscreen characteristics

The aerosol sunscreens tested were commercially available in Australia during August 2020 and all products had a SPF of 50 or 50+ (Figure 6, Table 1). Several companies had multiple aerosol products available, which were unique formulations and were included in the testing. Two Neutrogena® products and four Banana Boat® aerosol products were tested while one product each from the brands Hawaiian Tropic®, Surf Life Saving® and Woolworths® were tested.

Figure 6. Aerosol Sunscreen Products tested.

Table 1. Characteristics of Aerosol Sunscreen Products tested.

Brand	Product name	Active Ingredients	Batch number/expiry	Price (RRP)* $	SPF	Product ID number
Neutrogena®	Ultra Sheer Body Mist Sunscreen	Oxybenzone, Butyl Methoxydibenzoylmethane, Octyl Salicylate, Homosalate, Octocrylene	LOT20790111 EXP06/2022	14.99	50+	1
Neutrogena®	Beach Defence Sunscreen Spray	Homosalate, Octocrylene, Octyl Salicylate, Butyl Methoxydibenzoylmethane	<B>1090.359 EXP NOV 2022	16.99	50	2
Banana Boat®	Simply Protect Kids Spray	Homosalate, Octocrylene, Octyl Salicylate, Butyl Methoxydibenzoylmethane	19233FF EXP 07/2022	17.99	50+	3
Banana Boat®	Sport Cool Zone Spray	Octocrylene, Oxybenzone, Butyl Methoxybidenzoylmethane	1901AF EXP12/2021	17.99	50+	4
Banana Boat®	Ultra Clear Spray	Homosalate, Octocrylene, Oxybenzone, Octyl Salicylate, Butyl Methoxybidenzoylmethane	18274BF EXP 09/2021	16.49	50+	5
Banana Boat®	Dry Balance Clear Spray	Homosalate, Octyl Salicylate, Oxybenzone, Butyl Methoxybidenzoylmethane, Octocrylene	17288DF EXP 09/2020 and 19129BF EXP 04/2022	17.99	50+	6
Hawaiian Tropic®	Tropic Silk Hydration Sunscreen Spray	Homosalate, Octyl Salicylate, Oxybenzone, Butyl Methoxydibenzoylmethane, Octocrylene,	18127AF EXP 04/2021	18.99	50+	7
Surf Life Saving®	Sunscreen Sport Spray	Butyl Methoxydibenzoylmethane, 4-Methylbenzylidene Camphor, Octocrylene, Bemotrizinol	<B>1088471 EXP 10 22	16.49	50+	8
Woolworths®	Sunscreen Spray Everyday	Homosalate, Octocrylene, Octyl Salicylate, Butyl Methoxydibenzoylmethane, 4-Methylbenzylidene Camphor	<B>1092529 EXP 02 2023	7.50	50+	9

*RRP= recommended retail price based on pricing for September 2020.

Determining the amount of Propellant in each Aerosol Sunscreen Product

The amount of propellant contained within nine commercially available aerosol sunscreen products is shown in Table 2. The proportion of propellant in aerosol sunscreen products varied between products and ranged from 83%-27%. The Banana Boat® range consistently contained around 30% propellant in the four products tested (Table 2, Product ID 3-6). While the two Neutrogena® products tested contained 60% and 38% propellant respectively in product ID-1 and ID-2. The Surf Life Saving® aerosol product (ID-8) had the highest proportion of propellent with 83% of the product escaping during the degassing procedure (Figure 7).

Table 2. The amount of Propellant in each Aerosol Sunscreen product.

Product ID number	Net weight of Product*	Propellant			Lotion remaining (Sunscreen)
		Weight		Proportion of product	Proportion of product
	(g)	(g)	(SE)	(%)	(%)
1	140	84.78	8.7	60.56	39.44
2	184	71.26	2.3	38.73	61.27
3	175	47.81	0.3	27.32	72.68
4	175	56.81	1.3	32.46	67.54
5	175	48.74	0.5	27.85	72.15
6	175	51.13	3.6	29.22	70.78
7	175	48.77	0.85	27.87	72.13
8^	175	145.36	1.5	83.06^	16.94^
9	175	70.31	1.6	40.18	59.82

*The net weight for each product is printed on the label and has been transcribed into the table.
^ Product produced a foaming liquid during the degassing protocol, which may of have caused the sunscreen lotion to be included in the propellent fraction.

During the degassing protocol, the Surf Life Saving® aerosol product was observed to undergo a process of gas escaping for the first minute of the procedure and then a bubbling foam was observed (Figure 7, Appendix Multimedia File-1). The release of a bubbling foam was observed in all three Surf Life Saving® aerosol products tested.

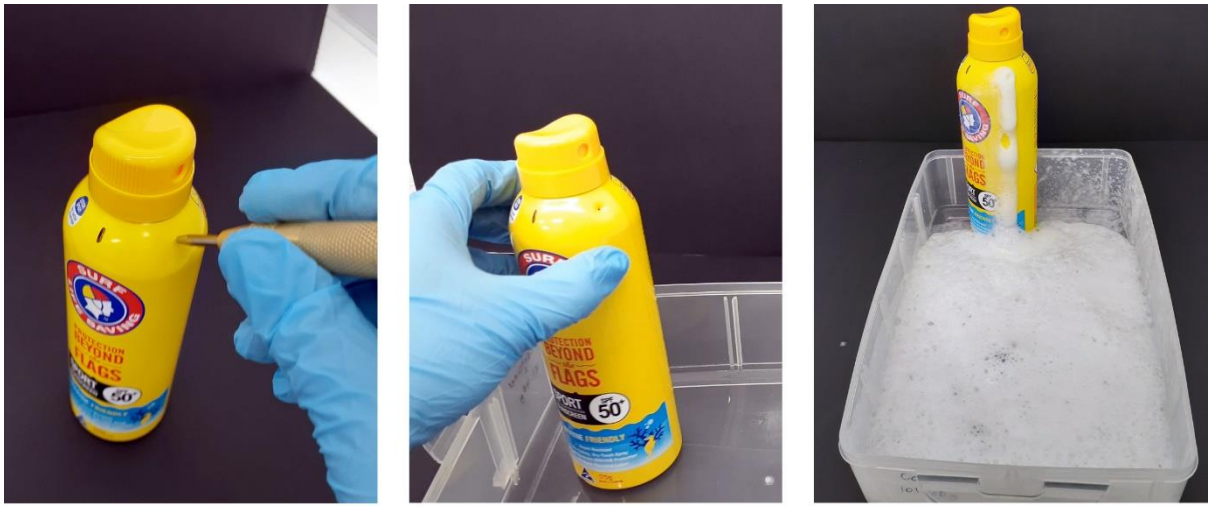

Figure 7. Observations during the degassing process for the Surf Life Saving® Aerosol Sunscreen Product. *Left panel,* a pin hole was made to the pressurized can for the propellent gas to escape. *Centre panel*, the pin hole allowed propellent gas to escape. *Right panel*, bubbling foam was observed escaping from the pin hole and the foam was collected in a plastic container. The foam was not included when the can was weighed after 24 hours and was therefore considered part of the propellent fraction.

The cost of each product (price per 100g) was calculated following adjustment for the amount of propellant present. The recommended retail price (RRP) shown in Table 1 was used to calculate the price per 100g of sunscreen for each product. There was a range between products with ID-1 $27 per 100g, ID-2 $15 per 100g, ID-3 $14 per 100g, ID-4 $15 per 100g, ID-5 $13 per 100g, ID-6 $15 per 100g, ID-7 $15 per 100g, ID-8 $56 per 100g, ID-9 $7 per 100g. As a comparison measure the price of a 100ml 50+ cancer council tube of sunscreen costs appropriately $13 per 100g. A limitation when estimating costing for aerosol sunscreen products is the constant variation in price with the purchase price often varying and many retailers selling products at prices cheaper than the RRP.

Determining the Flow Rate and Sunscreen Coverage of each Aerosol Sunscreen Product.

The flow rate was determined using a 10 second duration of use and is shown in grams per second in Table 3 and Appendix Multimedia File-2-4. The flow rate data was then used to calculate the time required to spray a new product and achieve adequate coverage including 5g per limb and 35g for a whole body. The spray time required to provide adequate coverage varied greatly between the aerosol sunscreen products tested and ranged from 4 -14 seconds per limb. The four Banana Boat® products tested varied ranging from 14 seconds per limb for the product ID-3 to 9 seconds for product ID-5. The two Neutrogena® products tested also varied with 13 seconds and 6 seconds per limb respectively for product ID-1 and ID-2 (Table 3). The Surf Life Saving® product (ID-8) reported the shortest spray time, however a thick foam was generated with a similar consistency to shaving foam (Figure 8). The ability for the foam dispersed from this product to form a protective film of sunscreen on the skin is unknown. The Woolworths® aerosol product (ID-9) had the longest spray time requiring 14 seconds for a limb and 98 seconds for a whole body.

Table 3. Flow Rate determination for a 10 second duration of spray.

Sunscreen Product ID	Flow rate Average (g/sec)	Standard Error (SE)	Spray Time per limb 5g (sec)	Spray Time per body 35g (sec)
1	0.40	0.01	13	88
2	0.84	0.05	6	42
3	0.36	0.02	14	97
4	0.56	0.05	9	63
5	0.58	0.01	9	61
6	0.45	0.01	11	77
7	0.63	0.01	8	55
8*	1.22*	0.04*	4*	29*
9	0.36	0.003	14	98

*Product produced a foaming lotion, which expanded and overflowed collection vial.

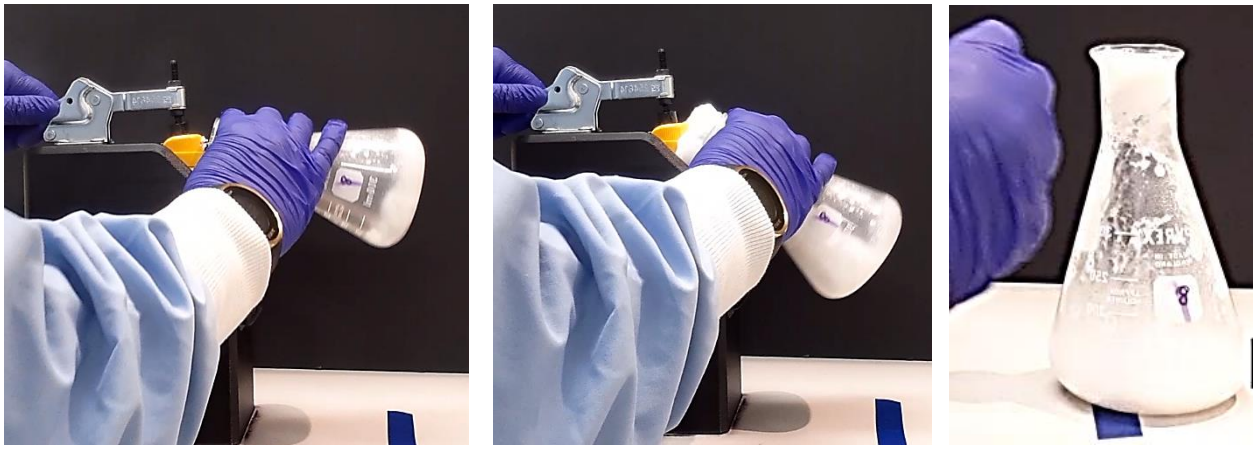

Figure 8. Observations during the flow rate protocol for the Surf Life Saving® Aerosol Sunscreen Product. *Left panel,* the actuator device disperses sunscreen from the bottle into a collection vial. *Centre panel*, after 8-10 seconds of continual dispersing of sunscreen a foam forms and starts expanding and overflowing out of the collection vial. *Right panel*, bubbling foam is observed in the collection vial.

Determining the length of time each Aerosol Sunscreen Product can be sprayed and the flow rate produced over the course of spraying the entire contents of each product.

The total duration of time required to spray a product until it was empty is shown in Table 4. The spray time required to empty the contents of the aerosol sunscreen products tested ranged from 190 - 452 seconds or 3 minutes to over 7 minutes. The four Banana Boat® products tested ranged from 305 seconds for ID-4 to 430 seconds for product ID-3. The two Neutrogena® products tested were similar with 234 seconds and 201 seconds for the product ID-1 and ID-2 respectively. The Surf Life Saving® product (ID-8) reported the shortest spray time and a thick foam lotion was collected (Figure 9). A flow rate calculation was performed using the duration to spray the entire product and the weight of the total product dispensed (Table 4). The total product dispensed from each product was used to estimate how many applications to an adult body (35g) one product could provide (Table 4). The two Neutrogena® products and the Woolworths® product (ID-1, ID-2 and ID-9) could adequately cover 2 people. While the Banana Boat® products, Hawaiian Tropic® product and the Surf Life Saving® product (ID-3, ID-4, ID-5, ID-6, ID-7 and ID-8) could adequately cover 3 people. The amount of sunscreen dispensed from each product also appeared to vary as the products' contents were emptied (Appendix Multimedia File 5-14).

Table 4. The length of time each Aerosol Sunscreen Product can be sprayed, and the flow rate produced over the course of spraying the entire product.

Sunscreen Product ID	Time to empty the contents of 1 bottle (sec)	Flow rate Average for bottle (g/sec)	Spray Time per limb 5g for bottle (sec)	Spray Time per body 35g for bottle (sec)	How many adult applications per bottle	Observations on the lotion collected
1	234	0.33	15	107	2.2	Clear Liquid
2	201	0.50	10	70	2.9	Clear Liquid
3	430	0.27	19	130	3.3	White Liquid with solids
4	305	0.41	12	86	3.6	Clear Liquid
5	390	0.30	17	118	3.3	Clear Liquid
6	390	0.31	16	112	3.5	Clear Liquid
7	270	0.42	12	84	3.2	Clear Liquid
8	190	0.60	8	58	3.3	White Foam
9	452	0.21	24	169	2.7	White Liquid

Figure 9. Observations from the experiment spraying the entire product. *Top panel,* the output collected from products ID-1, ID-2 and ID-3. *Centre panel*, the output collected from products ID-4, ID-5 and ID-6. *Bottom panel*, the output collected from products ID-7, ID-8 and ID-9.

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Appendix

Multimedia File 1. The degassing protocol for the Surf Life Saving® Aerosol Sunscreen Product.

[File name- FILE1_degass_surflife_product.mp4]

Multimedia File 2-4. The flow rate determination procedure of Aerosol Sunscreen Products.

[File name- FILE2_flowrate_Aerosol_Protocol.mp4]

[File name- FILE3_flowrate_Aerosol_Protocol25.mp4]

[File name- FILE4_flowrate_Aerosol_Protocol09.mp4]

Multimedia File 5-14. The length of time for a new product to be sprayed before the Aerosol Sunscreen Product was empty.

[File name- FILE5_ product_ID01.mp4]

[File name- FILE6_ product_ID02.mp4]

[File name- FILE7_ product_ID03.mp4]

[File name- FILE8_ product_ID04.mp4]

[File name- FILE9_ product_ID05.mp4]

[File name- FILE10_ product_ID6.mp4]

[File name- FILE11_ product_ID7.mp4]

[File name- FILE12_ product_ID8.mp4]

[File name- FILE13_ product_ID9.mp4]

[File name- FILE14_EmptyBottles.mp4]