THE WATER, ENERGY AND SOIL REMOVAL EFFICIENCY OF A TOP AND A FRONT LOADER WASHING MACHINE

by

KGALALELO SEIPHETLHENG

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Supervisor: Professor H. J. H. Steyn

DECLARATION

I declare that the dissertation hereby handed-in for the qualification Masters in Home Economics at the University of the Free State, is my own independent work and that I have not previously submitted the same work for a qualification in another university/faculty. I further cede copyright of the dissertation in favour of the University of Free State.

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K. Seiphetlheng

Bloemfontein

November 2011

DEDICATION

I would like to dedicate this qualification to my father Kgakgamatso "Silver fox" Seiphetlheng (late) and mother Laiza Seiphetlheng for the great support they have given me in life, I love you so much and thank for everything you have done for me.

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CHAPTER ONE

1.1 Background

Washing laundry is an activity that found in every household and nation. It may differ in the way it is carried out but water and energy (electricity or manpower) are the resources used. Washing machines have been invented and developed as apparatus that makes laundry in the shortest time possible without much attention. Various washing machines from different manufacturers are available. There are a variety of washing machines like front loaders, top loaders and twin tubs (Pakula & Stamminger 2009:6) available in the market and these use water and energy differently depending on the mechanical make up. It is upon the consumer to make a choice of a good machine that will clean their laundry well but also use less water and energy. Washing machines have penetrated the market at a very high level as it is considered a need to most families.

Sim *et al.* (2007:29) state that, in the UK 93% of households do own washing machines which use 14% of domestic water. In Bloemfontein South Africa 39% (Seiphetlheng2010:24) do own washing machines. On another note in 2002 South Africa used 35.6% of the total energy used in Africa (Sonnenberg *et al.*2011:154) this number has surely increased as the demand for electronic gadgets, which are labour saving has increased with changing lifestyles. A need to educate consumers about making choices that saves energy and water is vital for the benefits of the environment.

The consumer often has the claims of an advertisement and the word of a sales person as information when they purchase a washing machine. Sim *et al.* (2007:29) state that, machines use approximately 50 litres per wash while others state that, it uses 90 litres of water per wash (Lloyd 1998:696). If more loads are done then more water would be used resulting in the family paying more water bills and the environment suffering. As mentioned above energy is also needed for a washing machine to operate but just like water, a large amount of energy is needed. Lloyd (1998:695) states that, clothes washers and dryerŝ use heaping amounts of energy through operation and heating as the heating process uses 90% of the energy used by a washing machine. It is therefore of great importance that laundry is done on full loads to reduce the frequency or number of loads to save energy and water.

Companies claim that they manufacture washing machines to keep up with the needs of the market (Worsdorfer 2010:13). Currently in our market, consumers are using various brands of front loaders, top loaders and twin tubs to do their laundry. All these machines have a common objective of washing clothes but their efficiency in terms of water and energy consumption and soil removal are unknown to the consumer, which calls for an investigation. Sergio *et al*. (2002:332) says, ñDesign features of washing machines and other domestic objects have been changing throughout the years, however, energy efficient and more ecological machines are actually important design concernsò. Electricity and water are very scarce resources in the Southern African region and the tariffs are going up frequently, it is therefore important to select and use our household equipment well to save electricity and water. Top loader machines are much cheaper to purchase and often the more appealing to the consumer.If a top loader 8 kg washing machine of a specific manufacturer cost R1399.00, 8.5 kg front loader washing machine from the same manufacturer cost R 2599.00 (Game stores advertiser, Bloemfontein 2011) a consumer is likely to purchase the cheaper washing machine. The researcher observed that, in most retail stores top loader are cheaper and larger in capacity as compared to front loaders that are expensive but smaller.This laboratory based research aims at comparing the energy, water and soil removal efficiency between a front and a top loader washing machine.

1.2 Problem statement

Washing machines do use substantial amounts of energy and water; the researcher would like to compare a front and a top loader washing machine to determine whether the one is more efficient than the other. Washing machines are considered essential labour saving devices in many homes, but the cost in terms of water and electricity is not clear to the consumer. Consumers often select a top loader machine on the lower prices of it and the promise of energy saving with cold water wash but they do not have the benefit of comparing the soil removal efficiency and water consumption in a scientific manner. Therefore, the study aims at comparing a top and a front loader washing machine available in the market to determine the amount of water and electricity used and the soil removal efficiency during laundering. This information can be used to advice consumers.

1.3 Aim

The aim is to determine the water consumption, energy consumption and soil removal efficiency of a front and a top loader washing machine from the same capacity and the same manufacturer.

1.4 Objectives

1. To measure the amount of water used by the front loader and top loader washing machine.
2. To measure the amount of electricity consumed using various temperature levels, cycles and programmes of the washing machine.
3. To measure the water used per load during laundry with different programmes of a top and a front loader washing machine.
4. To determine the soil removal efficiency of the top loader and front loader machines at different temperatures and different programmes.
5. To measure the amount of electricity used by different cycles of the front and top loader washing machines.

1.5 Hypotheses

The hypotheses of the study are:

1. The top loader will use more water than the front loader washing machine.
2. The top loader washing machine would use less energy than the front loader washing machine.
3. Laundering at a high temperature will use more electricity.
4. The front loader washing machine would be more efficient in soil and stain removal than the top loader washing machine.
5. The quick program will use less energy than the daily program.
6. The quick program will use less water than the daily program.
7. The quick program will remove less soil and stains from the fabric than the daily program.
8. Soil re-deposition will not take place during the quick or daily wash program of the top and front loader washing machines.

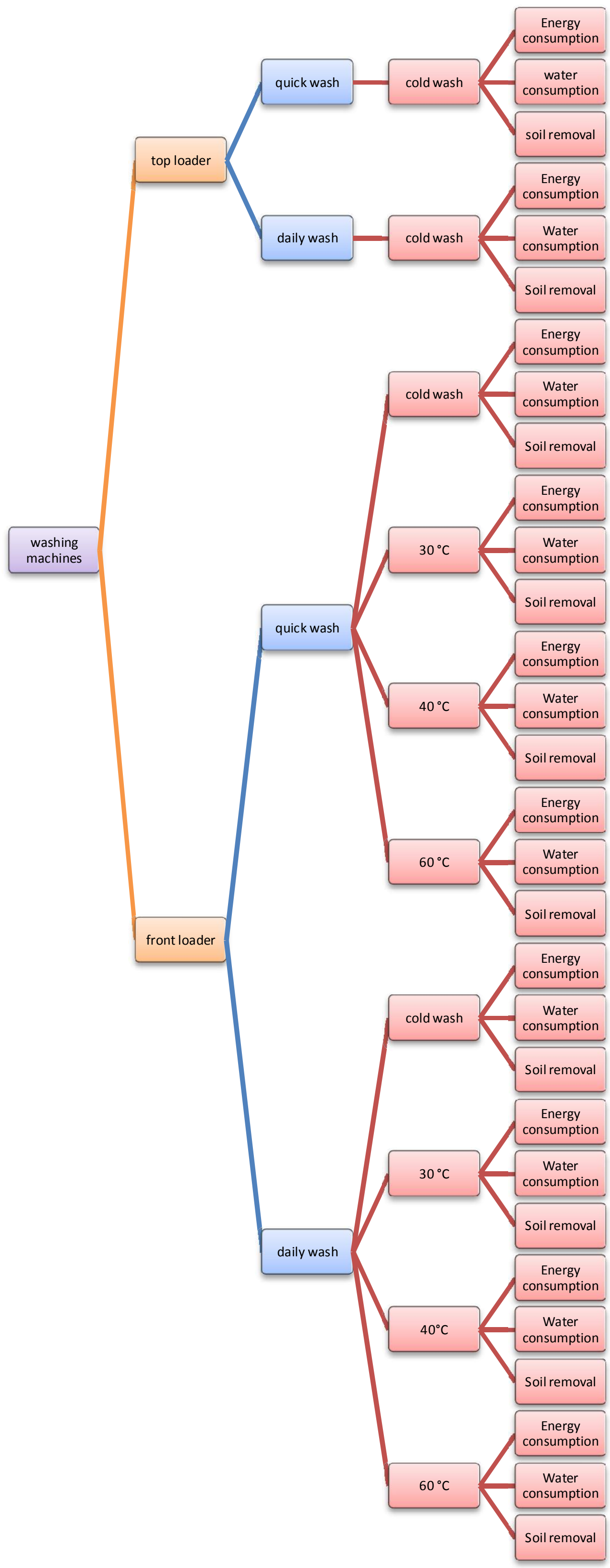

Figure 2: Conceptual framework chart

1.7 Operational Definitions

- **Domestic automatic washing machine**

These are home labour saving devices used to wash clothes. Automatic washing machines wash, rinse and spin clothes without help from the operator as electricity and water supplied will ensure the machine stops when it is done with a selected program (Sabaliunas *et al.* 2005:142).

- **Laundering**

The process of removing soil from textile where water and detergents are used to effectively remove soils and stains in laundry (Sabaliunas*et al.*2005:142).

- **Soil Removal Efficiency**

Soil removal efficiency is the level/rate at which soiled fabrics are cleaned after washing. It can be assessed by the rate of colour change in a standardized laboratory soiled test fabrics before and after washing (Eva *et al.* 2009:319)

- **Soil**

Dirt, oil or other substances not normally intended to be present on a substrate such as textile materials (AATCC technical manual 2010:207).

- **Stain**

A local deposit of soil or discoloration on a substrate that exhibits some degree of resistance to removal as by laundering or dry cleaning (AATCC technical manual 2010:207)

CHAPTER TWO

2.1 Introduction to literature review

Washing clothes is a domestic activity in human society, and for most it is an endless chore. The way people wash their clothes remained unchanged until the emergence of mechanical clothes washers for domestic use (Lin & Iyer 2006:3046). Clothes washers are considered one of the greatest human inventions that rescued women from their daily chores. To wash clothes, it is necessary to rub and flex the cloth so as to break away the solids and for the detergent to penetrate. Salaliunas *et al.* (2005:142) state that, at first clothes used to be pounded or rubbed with rocks in a river and later a corrugated wash board was developed. However, this all changed as it only takes one to press a button in a washing machine and the laundry will be done in no time without using any manpower like back in the old days, and one is able to continue with other chores whilst the laundry is done (Sergio *et al*. 2003:331, Ledger 2009:21).

Ledger (2009:21) point out that garments were hand washed dependant on fibre type and colour. “Boiling was often used to freshen, bleach and purify clothes, removing excess water from garments required the use of a wringer and it was dried by hanging outside” explains Ledger (2009:21). Damping (sprinkling with water) was required once a garment was dry to achieve optimal ironing or mangling results. The author further states that, chemicals were also used for the bleaching of garments that were in a bad condition. However, the arrival of the washing machine, with the combination of wash, rinse and spin in the drum, brought the freedom of choice but it was not the end of hand wash (Ledger 2009:21).

The earliest washing machines were made of wood (Durfee &Tomlinson 2001:32), hence the difficulty in heating the water. Later they were made of metal permitting fire to be burnt below the wash tub to keep the water warm during washing. Durfee & Tomlinson (2001:32) further mention that, it was a separate process to remove soap and water from clothing after washing as, the soaking wet clothing would be formed into a roll and twisted by hands so as to extract water. Even though, there was a washing machine it needed more attention unlike the current machinery (Durfee & Tomlinson 2001:32).

2.2 History of washing machines and dryers

The scrub board was invented in 1797 as the earliest washing machine (Lin & Iyer 2006:3046). Later, an American James King patented the first washing machine with a drum in 1851 and the manually powered drum he used then resembled the modern washing machine. Between 1851 and 1871, approximately 2000 patents were granted in Great Britain and America for a variety of washing appliances which had to be filled with heated water and used either rotating drums, gyrators or dollies to agitate the clothes (Sergio *et al.* 2002:332). Hamilton Smith invented the first rotary washing machine in 1858 (Stalmans & Guhl (2003:18). Sergio *et al.*(2002:232) explain that, most of these machines needed to be hand cracked and clothes tended to get tangled around the rotating dolly elements. Water was heated using gas burners that lead to problems when operating the machine. Around the same period in 1800, Stalmans & Guhl (2003:18) state that the first clothes dryers that were hand powered were used to dry clothes.

In 1874 William Blackstone built his first hand driven wooden washing machine, and the company still produces and sells washing machines to date out of their New York headquarters (Stalmans & Guhl 2003:18-19). The authors further state that, wooden wash tubs were replaced by metal tubs in the early 1900s. However, a wooden tub washing machine with a flywheel, still manually operated with a rotary handle was manufactured in 1907 by Maytag Corporation.

In the first decade of the 1900s, electric motors were incorporated into the design of washing machines but manual systems still predominated until the 1920s (Palan & Dannels 1997:1, Stalmans & Guhl 2003:19). Alva J. Fisher invented the first electric powered washing machine in 1908 (Stalmans & Guhl 2003:19).In the same year (1908) the Thor was introduced by Hurley Machine Company in Chicago, IIIinois (Stalmans & Guhl 2003:19). Authors further state that, Whirlpool Corporation around 1911 started producing electric motor driver wringler washers.And they further add that, the first electric clothes dryers appeared in 1915.Below is the diagram of a washing machine used in 1920 (Sergio *et al*. 2002:332-334).

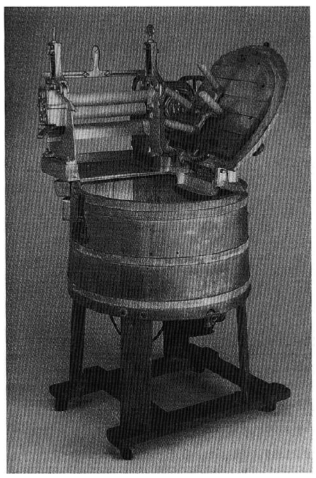

Figure 2: Wooden domestic washing machine with a dolly-style agitator, 1920.

When the availability of electric power grew so did the use of domestic washing machines, however water heating still remained a problem but it was resolved by end of World War II. During the post war years, some companies produced sleek, top loading washing machines that incorporated mangle like wringers and some had improved automatic controls that required less supervision (Sergio *et al.* 2002:332).Stalmans & Guhl (2003:20) further indicate that, in 1930s a machine that can wash, rinse, and extract water from clothes in a single operation was invented by John W. Chamberlain of Bendix Aviation Corporation.Below is the diagram of a washing machine used in 1932 (Sergio *et al.* 2002:332-334).

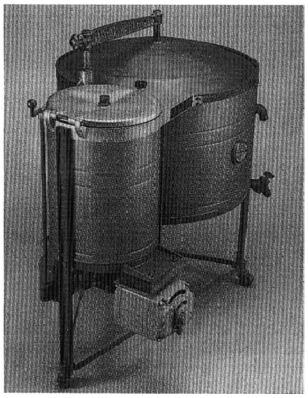

Figure: 3. Riby twin-tub washing machine, 1932.

By end of 1940s electric machines were fitted with an impeller, during the 1950s a heating element and automatic spin cycle were added (some machines had separate spinners, alongside the wash drum) explain Stalmans & Guhl (2003:20). They further explain that the first top-loading automatic washing machines were introduced by the forerunner of the Whirlpool Corporationin 1947. As technology advanced, in 1950ôs the first automatic washing machines (front and top loader) were made in Europe and they were the first computer-controlled automatic washing machines. The agitator and tumbling system are the only two washing systems among hundreds tested that are still in use today. There has been wash cycles and products developed to match new fabrics and wash conditions. By 1960s, automatic washing machines were easier to use than before as, at the touch of the button, wash, rinse and spin were done in the same drum. Below is the diagram of washing machine used in 1961 (Sergio *et al*. 2002:332-334).

Figure 4: Front-loading washing machine, 1961.

Throughout the 20th century there has been new technological developments that emerged as electromechanical controls (knobs) had been replaced by electronic ones (push-buttons), the newer machines required less water and newer laundry products worked better at lower temperatures, rendering the laundry process more energy-efficient (Stalmans & Guhl 2003:21). However, in the 21st century much attention is drawn to more environmentally friendly models. Some models claim to be completely recyclable and new wash cycles were introduced, such as those for silk, wool and delicates, and a short wash. In spite of all these technology, manual practices of doing laundry still exist as electricity and running water are not installed in all homes for a smooth operation of the washing machine.

2.3 How Washing Machines Operates

The two most common machines that were invented are the top loader and the front loader. According to Palan &Dannels (1997:1) top loading machines were developed in the 1940ós and front loaders in 1945. Today washing machines are made from various materials like plastic and metal. When electric motors were developed water removal by spinning came into use (Ledger 2009:24). Ledger (2009:24) further mention that, spinning required a high speed power source and it was originally done by a separate device known as the extractor ï a load of washed clothes would be transferred from the wash tub into the extractor basket and the water would be spun out. The twin tub machine does not follow through the process automatic but works differently as spinning is done on a separate tub whereas washing and rinsing is done in another tub. Washing machines are referred to as automatic when the wash, rinse and spin of the clothing is done by the push of the button without much of your attention unlike the above described.

Palan & Dannels (1997:3) mention that, the front loading washing machine had undergone major technological changes over the years. They explain the difference between the front loader and top loader as follows: the front loader (horizontal axis) use tumble action while the top loader (vertical axis) utilize an agitator that actually force clothes to beat against each other, while the front loader lift and tumble clothes in and out of the water without rough agitation. Top loaders also have being upgraded as they use the tumble action that is used by the front loader.

Koester (1992:1) states that, automatic washers are available in compact and full sizes, the full size washers have either a standard tub or large tub as the construction varies according to brands. The author further mentions that, all automatic washers have an inner tub which holds the clothing being laundered and an outer tub, which holds the water and the inner tub. One great development in the top loader and front loader washing machines is that, they set water levels automatically, ensuring efficient use of water (Consumer reports 2006:79). The report further indicates that, most machines establish wash and rinse temperatures by mixing hot and cold water in preset proportions, and these are great features needed to save energy and reduce attention of the machine operator.

The need to own a washing machine has increased with years especially in developed countries (Worsdorfer 2010:12), at present, four out of five U.S. households own an electric, automatic washing machine, which in comparison to the 19th century conditions, made not only time savings, but more importantly, substantial reductions in physical effort. Laundry washing can no longer be called a ñbackbreaking labourò today. Additional Worsdorfer (2010:12) states that, at present, the majority of households in industrialized countries use washing machines to ensure cleanliness. When compared with previous years, the need for a washing machine has really grown as in 1997, over 70% of American households have and use a clothes washer in their homes (Shel Feldman Management Consulting Research Into Action 2001:22). In 2010 it was reported as 83% of all U.S. households had washing machines, pointing to a saturated market and in the U.K., even 92% of all households are equipped with a clothes washer while in Germany 95% of households own a washing machine (Worsdorfer 2010:13). However, in a study in 2010 in Bloemfontein, South African only 39% of households possessed a washing machine indicating that it is still a luxury item in poor households.

About 90% of the energy expended for washingclothes is used to heat the water, to reduce the amount ofenergy used to wash and dry a load of clothes; youneed to use less water at a lower temperature.Therefore, they advise to use cold water whenever possible, andonly wash full loads if your machine has noadjustment for load size (Lee *et al*. 2008:24).

2.4 The general elements of front and top loader washing machines and their actions

2.4.1 Basket

The inner drum and the outer drum are the most important parts of a washing machine (Dunn *et al.* 2008:23). The authors explains that, the inner drum is the one you can see when you open the door or the lid and have a basket riddled with holes that sits in a tub. Laundry is pushed from inside the door from the front and the whole drum rotates. Before activating the machine the detergent is added to the laundry. Dunn *et al.* (2008:23) further explain that, the drum has lots of small holes to let water in and out and paddles around the edge to slosh the clothes around. And the outer drum is the bigger drum outside the inner drum, which is used to hold the water while the inner drum rotates. Unlike the inner drum, the outer drum has to be completely water-tight. Besides the two drums, there are many other components. There is a thermostat (thermometer mechanism) to test the temperature of the incoming water and a heating element that warms it up to the required temperature, an electrically operated pump that removes water from the drum when the wash is over Dunn *et al*. (2008:23).The authors further explain that, there is a mechanical or electronic control mechanism called a programmer, which makes the various parts of the washing machine go through a series of steps to wash, rinse, and spin your clothes and there are two pipes that let clean hot and cold water into the machine and a third pipe that lets the dirty water out again.

2.4.2 Water

The top loader washing machine is directly connected to hot and cold water lines installed in the house, while the front loader is connected to only the cold water tap and it has an element which will heat the water during laundering. When activated, the tub and basket will fill with either hot, cold, or warm water, depending on the chosen temperature or program and the type of machine used. Once the tub fills with water, the turbine spins to agitate the laundry in the basket. Eventually the water will turn soapy from the detergent and after a few minutes of agitation, the turbine will stop spinning and allow the laundry to soak in the detergent (Sheilds 2011:1). Motors in the machine use belts wrapped around the base of the turbine to spin the agitator. According to Sheilds (2011:1) after the machine agitate and soaks the clothes in the soapy water, it will agitate the laundry again to free some of the detergent from them and then drain the water from the tub. In some machines, the water will drain through the same water lines, while in older models the water will drain via a separate line. It all depends on the type of machine used.

2.4.3 Capacity

According to Barton (2010:1) front load washers have a larger capacity than a top load washer the same size.This is because a front load washer does not have an agitator in the center taking up space like the top loader. Austin *et al*. 2007:30 explain that, since is no central agitator in the front loader, the drum can hold 20-30% more clothes than the top loader. Front-load washers have a door on the front of the unit for loading clothes while, top-load washers have this door on the top of the washer and typically hold more water than their front-loading counterparts (Lilley 2011:1). Front loaders can handle a much larger load than the top loader. Through observation around various stores supplying washing machines, in South Africa top loaders are usually bigger and can handle larger loads than front loaders.

2.4.4 Agitation

A top loader washer spins at between 600 and 700 rotations per minute whilst a front load washer spins at more than 1,000 rotations per minute (Barton 2010:1). Which means a front loader washing machine can spin water out of the laundry more completely and laundry will dry faster. Gardapee (2011:1) further explains that, top loader washing machines spin clothes around in the drum, as the agitator turns the drum on a vertical axis to wash the clothes and spin out water, whilst the front loader tumble the clothes during the wash cycle.As the drum turns on the horizontal axis, clothes drop back into the water (Gadapee 2011:1). On the spin cycle, clothes tumble to remove the water. McClain (2011:1) adds that, front-loading washing machines tumble clothes through a pool of water and detergent, whereas top-loading machines use a central agitator spire to grab and pull clothes through the water. While any kind of washing is going to do some minor damage, the tumbling in a front-loader does far less damage than of a top-loader (McClain 2011:1).

2.4.5 Efficiency

Top loader machines are less efficient at cleaning clothes and their high spin speeds can damage or tangle clothes (Red 2010:1). Furthermore, more detergent and water are needed in top loaders than in front loaders (Barton 2010:1). According to McClain (2010:1) since front loaders do not have to spin an agitator in the middle of the drum to scrub the clothes clean, they use less energy than the top loader model. Another factor is that, a front loader has less water to heat up so it saves a lot of energy that could be used in heating water, and these factors make the front loader to be more efficient than the top loader.

2.5 Top loader washing machines (Vertical-axis Washers)

The top loading models have become popular in America, but in Europe the front-loading washing machines have become standard (Sergio *et al.* 2002:332). Top load washing machines use more than double the amount of water used by front loaders. Front loaders use an average of 60.6 ± 15.7 litre per cycle, whereas top load washing machines use 138.9 ± 23.9 litre per cycle (Mead 2008:39). The author state that, it vary due to the different models, makes and sizes of the machines as well as different types of cycles used or the differing size of the loads.

2.6 Front loader washing machines (Horizontal-axis washers)

Front-loading washing machines are horizontal axis models which tumble laundry much like a dryer does (Consumer Energy Center 2011:1). This type of household laundry washer has a door in the front instead of an opening on top of the machine. Laundry is placed in a horizontally oriented stainless steel drum instead of a conventional tub with central agitator. The horizontal drum is partially filled with water, and cleaning occurs as the clothes tumble in and out of the pool of water at the bottom of the tub (Consumer Energy Center 2011:1). This action is gentler on clothes than a top loader washing machine, which uses an agitator to push and pull garments through a full tub of water. Consumer Energy Center (2011:1) states that front loaders cut water use by nearly 40%.

The U.S. Department of Energy did a study in a small town in Kansas in 2009, where 204 older top loading washing machines were replaced with horizontal axis machines. Homeowners there realized an average of 38% savings on water usage and 56 % energy savings for the washer and hot water heating system (Consumer energy center 2011:1). These more efficient machines offer other benefits as well. Front loaders cause less wear and tear on clothes. They can also spin more water out of the laundry, thereby reducing drying time (Austin *et al.*2007:30).

Ramasubramanian & Tiruthani (2009:1) agree that, horizontal axis washing machines are water and energy efficient and becoming popular in the USA. Unlike a vertical axis washer, these do not have an agitator and depend solely on tumbling for the agitation of laundry during the wash cycle. However, due to the constant shifting of laundry during washing, the load distribution is often unbalanced during the high speed spin cycle. McClain (2011:1) agrees that, the absence of a central agitator means that there is more room in a front-loading washer for clothes, allowing one to get more laundry done in the same amount of time. It is easier to wash large items, like comforters, in a front-loader as one does not have to wring them around a central agitator. Another good thing about front loading washing machines is that, it can also fit into places where a top loader cannot, like underneath counters or even stacked below of a dryer (McClain 2011:1). The figures below show how the horizontal and vertical axes are designed inside.

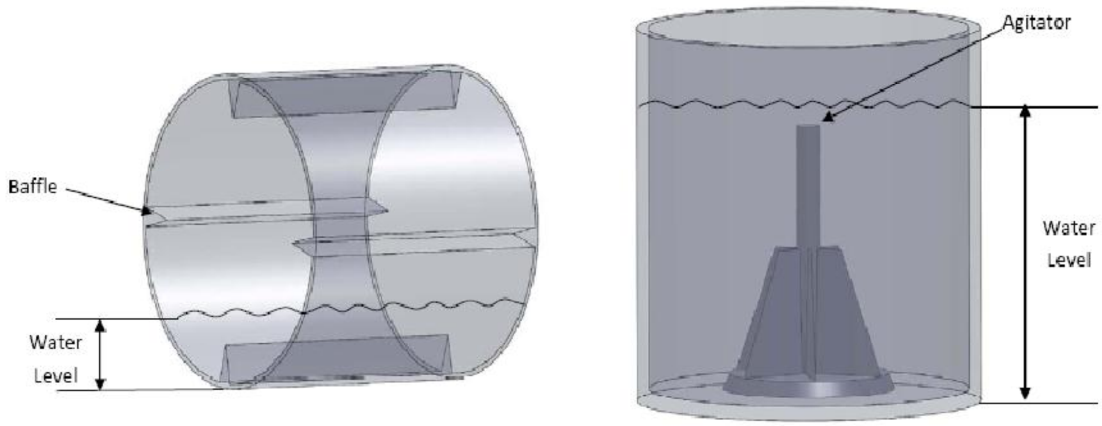

Figure 5: Horizontal and vertical axis washing machine configurations (Ramasubramanian & Tiruthani 2009:2).

2.6.1 Water consumption of the front loader washing machine

Yarra Valley Water (2010:1) states that, front loaders generally use about half the amount of water that a top loader consumes and this is mainly due to the drum spinning on a horizontal axis in a front loader, requiring it to be only half full to cover all the washing as it spins. However, using the adjustable water level on modern top loading machines enables the water used to be reduced as the size of the load reduces (Yarra Valley Water 2010:1).

Mead (2008:36) said that front loading washing machines are considered to be more water efficient than top loaders. Front load washing machines use an average of 60.6 ± 15.7 litre per cycle, whereas top load washing machines use 138.9 ± 23.9 litre per cycle (Mead 2008:36). This is a clear indication that top load washing machines use more than double the amount of water used by front loaders. However, the amount of water used would differ according to models of machines and size of loads. Austin *et al.* (2007:30) state the benefits of a front-loading washer as follows; use less water during each cycle; more clothes fit per load, and higher spin speeds during the rinse cycle causing clothes to dry more quickly. Consumer reports (2006:77) state that, even though traditional top loaders with agitators are going strong, front loading washing machines are gaining ground due to their good washing performance, large capacity, water and energy efficiency, and quiet operation. The author further describes the front loading machine as follows: it gets clothes clean by tumbling them in water; clothes are lifted to the top of the tub and then dropped into the water. Consumer reports (2006:77) further mention that, the machine will spin at high speed to extract water making the machine more efficient with water and electricity than regular top loaders.

2.6.2 Energy consumption and other benefits of the front loader washing machine

Clothes will also last longer with a front-loader, because they gently tumble your laundry instead of jerking them around with an agitator (Bluejay 2010:2). Front-load washers squeeze more of the water out of your clothes, hence less time to dry laundry. And since front-loaders lack the central agitator, it is easier to wash large items like bedspreads, rugs, and sleeping bags (Bluejay 2010:2). Though modern top loaders do not have central agitators which makes it easy to wash the same laundry as front loaders.

Bluejay (2010:2) further claims that, front-loaders sold in the U.S. generally have both hot and cold water connections, whilst European front-loaders generally have only a cold water connection, so the washer heats the water, electrically. U.S. front-loaders do mix the water to the proper temperature, same as with top-loaders. Front loaders in South Africa operates similar to European one's as they are only connected to cold water connection, there is a heating element in the washing machine which heats the water to the desired temperature from 20 ºC - 90 ºC. The temperatures may vary as washing machines are made by different manufacturers. Top loaders there are connected to the cold and hot water connections separately, the user has a choice of connecting both or only one.

As for energy consumption, front loaders are around twice as energy efficient as top loaders, providing savings on both electricity and water costs while minimising the impact on the environment (Yarra Valley Water 2010:1). The author further states that, electricity savings are mainly due to water efficiency, as less energy is required to heat a smaller amount of water. Moreover, due to the water efficiency of front loaders, a smaller amount of detergent is needed for the wash, providing both economic and environmental benefits. Mead (2008:23) also adds that, front loading or horizontal axis washers are more energy efficient than standard top loading or vertical axis machines. The author explains that, front loading models use about two thirds less water and are said to clean laundry more thoroughly than conventional top loaders. Another point the author states is that, front loading machines spin the laundry faster and remove more of the moisture content resulting in a shorter dryer time for the load. Palan & Dannels (1997:1) agree with the other authors that the front loader is an energy efficient washing machine as compared to the top loader when they state that in Europe high energy costs drove the market toward the front loading technology as it requires less water and energy to operate. In addition, Europeans believes that, the top loader cleaned better than the front loader (Palan&Dannels 1997:1). As for the South African market no literaturewas found to verify which machine launders better.

2.6.3 The disadvantages of front loading washing machines

2.6.3.1 Cost of washing machine

Front loading machines are more expensive than top loading washing machines. According to Schultz (2010:1), in saved energy costs over time the front loader recoups the initial high price. If one cannot afford the front loader, the top loader might be available within the budget.

2.6.3.2 Bending

When loading laundry in the front loader, one has to bend in order to reach the door, and people with back problems might find it difficult to bend to reach the door.

2.6.3.3 The door of the front loader washing machine

The doors on front loading washing machines have very thick seals made of rubber. Their purpose is to prevent water from leaking around the door. They also can trap detergent, water and dirt, which creates an environment that, encourages the growth of mold, mildew and musty odours (Schultz 2010:1). The author further states that, a couple of antidotes to this disadvantage are wiping out the seal with a dry rag after each use and leaving the door open when the machine is not in immediate use.

2.6.3.4 No last minute addition of laundry

With a top loader one can add other laundry that you forgot to include when the machine started to wash. As one just lift the lid on the top loader and toss the laundry item onto the rest. With the front loader once the door is sealed and the start button is activated, it will only stop when the machine has finished washing the laundry.

2.6.3.5 Use of special detergents

With a top loading washing machine, any washing machine detergent can be used but with a front loading machine most manufacturer instructions are specific about which kind of detergent to use (Schultz 2010:1). Schultz explains that, detergents used in front loaders must be low suds detergents identified as high efficiency (HE), which are becoming widely available and often more expensive than any other detergent that can be used in a top loader.

2.6.3.6 Long cycles

Wash cycles for front loaders are longer than the cycles of top loaders, and for heavy soil settings the front loader can take up to two hours to wash a load of laundry (Schultz 2010:1). Still with less intense settings, washing takes from one hour to an hour and half whilst top loaders take from half an hour to 50 minutes for an average load.

2.7 Soil Removal

In textiles, there are wide varieties of soils, and the soil are normally dispersed rather than being well spread across the fabric and some soils will only be located in one area of the textile. Johansson & Somasundaran (2007:64) mention that an alternative way to categorise soils is to group them according to the detergent functionality to remove the soil. Bajpai & Tyagi (2001:327) define soil as accumulation of unwanted oily or particulate materials on the surface or interior of fibrous structures.

2.7.1 Classification of Soil

2.7.1.1 Water soluble soils

These soils include salts from perspiration and food, urine and sugars as they are soluble in water hence the soils dissolve easily during rinsing. Some of these soils are dispersed through close contact to the body, atmospheric dust and some from washing cycles. Each human sweats and perspirate differently, the body produces dead skin cells and these adds to the various soils and stains on the textiles worn. However, Johansson & Somasundaran (2007:64) mention that some of those soils and stains can stress the surfactant and making the detergent less effective when laundering them.

2.7.1.2 Hydrophobic soils

These soils include mineral soils, greases from food, triglycerides and body oils which may be present as dispersed soil or stains. Grease stains are very noticeable as well as stain around cuffs and collars from sweating. Johansson& Somasundaran (2007:65) state that, hydrophobic soils have low energy and spread well on the fabric surface, these stains are not miscible with water and their removal need the presence of surfactants in the washing water. The surfactant lowers the surface tension of water allowing wetting of soil hence helping the removal of the hydrophobic soil from the surface and the soil will be suspended in the washing liquor.

2.7.1.3 Particulates

These are solid particles that are sticking to the fabrics and can be of mineral origin like clay and rust. They can also be organic in nature such as skin cell debris and biopolymers such as starch (Johansson & Somasundaran 2007:65). The authors further explain that, particulates are hydrophobic in nature as they associate with hydrophobic stains that makes their removal even more difficult, as they are water insoluble and need to be lifted from the fabric and suspended in water. The key ingredient to the removal of these stains are surfactants as they facilitate wetting and soil suspension, as well as builders which help in breaking bridges between particles formed by divalent cations. To avoid re-deposition of the suspended particulates, anti-redeposition polymers are added to detergents (Johansson & Somasundaran 2007:65).

2.7.1.4 Bleachable stains

They include stains from tea, wine, tomatoes and berries, they are very difficult to remove as chromophores are present in hydrophobic matrix impending the removal of the stain (Johansson & Somasundaran 2007:65). Mere washing with detergent does not remove those kind of stains, bleaching might be required. The authors state that, bleach present in the wash water degrades the chromophores leading to the discoloration of the soil, even when the soil may not be completely removed it is generally no longer visually detectable.

2.7.1.5 Composite soils and ageing soils

Soils can interact physically and chemically thus changing their state and making the removal even more difficult than anticipated. Carbohydrates can interact chemically with proteins and lipids and that will transform the soil to be even more complex to remove than if they had not interacted.

2.7.1.6 Enzyme sensitive stains

Enzyme sensitive stains include proteins, dispersed body soil, proteins and starches in food stains, they consist of poorly water soluble polymers with a high affinity for textile fibres. Johansson & Somasundaran (2007:66) state that, the removal of these stains can be enhanced by the use of enzymes for example: protease degrades proteinaceous soil rendering the material more easily dispersible in the wash liquor and decreases the molecular weight of already solubilised proteins preventing redeposition; Amylase hydrolyses starch improving the solubility of this type of stain; and Lipase partly hydrolyses triglycerides boosting the emulsification of the hydrophobic residues while cellulase removes cotton microfibrils aiding the removal of trapped particulates.

2.7.2 Action of Cleaning

In order to understand the cleaning action of detergents it is appropriate to consider the mode of action of detergents in the laundry process. There are three methods available in order to accomplish the task- mechanical, thermal and chemical. Mechanical action plays an important part in the cleaning process, as it facilitates the removal of solid particles of dirt, which must then be suspended within the solvent detergent system. It also involves the bending and stretching of the fabric. The thermal method involves increasing the solubility of the soil in water. Whilst chemical involves chemical reactions between the soil and the detergent or fabric and detergent to remove the soil. All three methods complement one another as mechanical action at elevated temperatures with the correct detergent will remove the stain much better. Water alone is incapable of removing dirt, oils and fats; neither is water a good wetting agent for textile materials. Oils and fats are non-polar and are not attracted to water. Hence detergents become the key element of washing processes.

According to Fergusson (2008:18) cleaning occurs in five stages:

- Lowering the surface tension of water;
- Wetting of the solid surfaces by the water;
- Penetration of water into the porous solid;

- Removal and detachment of soil from its adhesion to a solid;
- Suspension, dispersion or emulsification of soils, dirt, grease and fatty matter.

In any cleaning process involving water it is essential that there is thorough wetting of the material by water. The reduction of surface tension of water and the wetting of the material are essential factors in the removal of oils, fats and dirt.

2.7.3 Action of the detergent

For good washing action to take place in the machine, it requires plenty of room (Wright 1994:1) to move around with enough detergent and the right water temperature for soil to be carried away from the textile fabric. Wright (1994:1) mentions that, the washing solution must be able to circulate through the fabrics to loosen and carry away soil, so the water level control on the machine must be set correctly for the load to be washed. Water alone cannot remove the soil in the fabric hence a detergent is needed. Cameron (2007:151) states that, laundry detergents may contain any number of ingredients designed to enhance the laundry process. Laundry detergents typically contain two major ingredients, a surfactant and a builder (Cameron 2007:151).

2.7.4 Surfactants

Surfactant (surface active agents) is an important ingredient in laundry detergent as it: improve the wetting ability of water, loosen and remove soil with aid of wash action, and emulsify, solubilize, and suspend soils in the wash (Bajpai & Tyagi 2007:329). Johansson & Somasundaran (2007:72) mention that surfactants are the largest contributors to the performance of laundry detergents as they act on most soils on a variety of mechanisms. Furthermore, surfactants form a protective coating around the suspended soil allowing the soil to be removed from the textile (Cameron 2007:152). Johansson &Somasundaran (2007:72) also add that, surfactants help overcome the incompatibility of water with oil and as a result of these properties surfactants are the key contributors to the removal of grease and oily soils. Surfactants absorbed at air-water-interfaces as well as soil-water-interfaces making them responsible for the foaming of detergent solution. Foaming does not add to the cleaning process but it is a signal of the presence of detergents in a wash solution but foaming can also be an unwanted product. Ponnusamy*et al.* (2008.1124) add that surfactants aid mobilisation, dispersion and emulsification of soils from the fabric surface. Laundry detergents may contain more than one kind of surfactant as they differ in the ability to remove certain types of soil, in their effectiveness on different fabrics and their response to water hardness (Bajpai & Tyagi 2007:329).

2.7.4.1. Types of surfactants

2.7.4.2 Anionic Surfactants

Linear alkylbenzenesulphonate (LAS) is an important anionic surfactant due to its excellent performance and low cost (Johansson & Somasundaran 2007:73). It is more resistant to curd formation than common soaps yet still sensitive to water hardness and can form insoluble calcium and magnesium salts. Its hardness intolerance is overcome by the addition of non-ionic surfactants.

2.7.4.3 Non-ionic Surfacants

Alkyl ethoxylates are the non-ionic surfactants most often used. They are incapable of complexing calcium or magnesium which makes them tolerant of water hardness. They are excellent as emulsifiers and for greasy stain removal (Johansson & Somasundaran (2007:74). The authors further explain that non-ionic surfactants help LAS solubility by forming mixed micelles and lime soap dispersancy and builders are added to bind calcium and magnesium ions.

2.7.4.4 Cationic Surfactants

Cationic surfactants are used less in laundry detergents due to their tendency to rapidly adsorb to and not to desorb from the fabric and the soil (Johansson & Somasundaran 2007:75). The authors further explain that, this property of adsorption on fabrics is used in fabric softening where double long chain surfactant-like molecules are the standard actives used in fabric softeners formulations. Furthermore, low levels of soluble single chain cationics can have a positive cleaning effect when mixed with anionic surfactants. Surfactants are easier to process and incorporate into liquid formulations than in powders where they can cause stickiness and caking, hence heavy duty liquid detergents contain higher surfactant levels than powder and generally offer better performance for the removal of greasy/oily soils (Johansson & Somasundaran 2007:75).

2.7.5 Builders

Builders are used to enhance the detergent action, and most builders also provide a desirable level of alkalinity and help to suspend and disperse soils and prevent their re-deposition and ensure good cleaning. Johansson & Somasundaran (2007:85) indicate that builders bind and neutralise the negative effects of hardness (calcium and magnesium) ions present in water and in soils. These ions insolubilise anionic surfactants such as soap, and builders are important in maintaining the efficiency of the surfactant. Another beneficial effect of builders (phosphate free detergents) includes; improvement of the removal of stains from blood, grass and beverages and improvement of whiteness. The second most important function of builders is to break up and disperse particulate soils and keep it in suspension for effective removal so that they cannot redeposit themselves on clothing (Bajpai & Tyagi 2007:330), which it does best with clay type soils. Moreover, complex phosphates and silicate builders can modify the absorption of the detergent on the substrate or soil and also act as suspending agent. Builders give the cleaning solution ñreserve strengthòto enable the detergent to withstand heavy soil loads (Ponnusamy*et al.* 2008.1124). Bajpai & Tyagi (2007:330) also add that, builders increase the efficiency of surfactants and they provide a desirable level of alkaline to aid the cleaning process.

The two types of builders are those that contain phosphorus (phosphates) and those that do not contain phosphates. Phosphates include pyrophosphates, tripolyphosphates and/or metaphosphates. These phosphates possess unusual power to remove and suspend clays, pigments and other finely divided solids in water solutions (Johansson & Somasundaran 2007:117). Laundry detergents generally come in two forms: powders (including tablets) or liquids. Some of these detergents are specifically made for heavy duty washing machines and some for domestic purpose but their main objective is to remove the soil (Cameron

2007:154). Different water temperatures can be used with various detergents but manufacturers of detergents always advice the water temperature that should work best. Cameron (2007:155) states that, converting to washing in cold water versus that of warm water saves money, and there are environmental benefits such as the reduction of energy to heat the water, thus less greenhouse gas emissions. The author further explains that, cold water detergents contain surfactants, enzymes, and builders much like other current detergents.

2.7.6 Enzymes

Enzymes are used to improve the cleaning efficiency of detergents and are considered the most valuable ingredients of granular and liquid detergents, stain removers and industrial cleaning products (Johansson & Somasundaran 2007:83). The authors further explain that, enzymes in laundry detergents are desirable since they are catalysts capable of being used at lower temperature levels than stoichiometric detergent ingredients. Moreover, they are biodegradable and help reduce washing energy consumption, as they lower the activation energy of breakdown soils and contribute at least in principle to the ability to lower the washing temperature.

2.8 Effects of water temperature on soil removal

Cleanness of washing is a function of many factors including water temperature, length of the washing cycle, detergents, washer designs, water quality, as well as the kind of textile (Lin& Iyer 2006:3048). Lin & Iyer (2006:3048) state that, Americans seem to use “warm wash” most often as 49% of washes are done in the warm cycle, and only 14% in the hot cycle. Whilst Japanese predominantly use cold wash– most Japanese clothes washers do not even have a temperature selector. The authors further state that, the Japanese market already uses detergent that is rich in enzymes and able to tackle protein as well as fat-based dirt removal even in cold temperatures. Heinzel*et al.* (2010:334) on another note conclude that, the process of laundering itself has improvedduring the last 20 years both ecologically and economically, especiallyby the reduction of temperatures and water consumption,and this development is still ongoing especially in Europe.Water is used as the solvent in washing because it is relatively cheap, readily available, non-toxic and requires no special attention. However, the hardness, temperature and volume of water used during washing affect the removal of stains in any given fibre (Kadolph 2007:417).

According to Terpstra (1998:170) traditionally heavily soiledlaundry, like kitchen towels, underwear and bed sheets,were washed with a white wash program at 95°C. And lightly soiled garments like blouses,dresses, shirts and skirts, mostly coloured articles werewashed in a wash programme at 60°C. The author further states that, as a substantialpart of the energy consumption is due to water heating, the wash temperatures of the above mentioned programmeshave been reduced to 60°C and 40°C respectively. Furthermore, to maintainan acceptable cleaning performance, the duration of themain wash and the mechanical action have both beenincreased. But even then the soil removal is lower, comparedto the programmes with higher wash temperatures. Terpstra (1998:170) has concluded that, several consumer bodies and researchers have reported alower soil removal for these low temperature programmes and affectthe hygienic quality of the washed laundry hence decrease the cleaning and hygienic performance of the laundering process.

Wright (1994:1) advices on the different water temperature and their effects on soil removal as follows:

a) Hot water: 70 -100 °C

Removes dirt from heavily soiled items, kills more germs than cold water, fades the dyes in some coloured clothes and tends to cause wrinkling in some modern fabrics such as permanent press.

b) Warm water: 40 - 60 °C

Usually gets lightly soiled clothes clean, does not kill germs unless a disinfectant is added and is safe for most coloured clothes.

c) Cold water: below 30 °C

For cold water below 30 ęC it requires a cold water detergent to get clothes clean (Wright 1994:1). The author further advices that, if a cold water detergent is not available, dissolve detergent powder in hot water before adding it to the wash water. However it requires more detergent than warm water to get clothes clean and does not kill germs unless a disinfectant is added. It is therefore recommended for washing some delicate fabrics.

2.9 The type of washing machine versus stain removal

According to Yarra Valley Water (2010:1), front loaders have an advantage in all market surveys, in stain removal due to the longer wash cycle and horizontal action. The author further explains that, front loaders are gentler on clothes than the harsher and more vigorous action of the conventional top loader. Even though, front loaders are often perceived to have a smaller capacity than top loaders, but with recent technological advancements, the capacity of front loaders has increased to be more comparable with the top loading machines.

2.9.1 Assessment of soil removal efficiency

When comparing colour from various sources using the naked eye, one is bound to vary, a colour you see today can be perceived differently the next time one views the same material. Hence scientific instruments like spectrophotometer, colorimeters and densitometer are used to evaluate colours in textiles accurately. These instruments create scales of hue, lightness and saturation to measure colour numerically and record it. In 1905 an American artist named A.H. Munsell devised a method of expressing colours using a great number of paper chips of different hue, lightness and saturation for visual comparison with specimen colours (Minolta 2007:17). Minolta (207:17) explains that, other methods for expressing colour numerically were developed by international organizations concerned with light and colour, the Commission Internationale de lõ Eclairage (CIE). The organization devised the L*a*b* colour space which provided more uniform colour differences. These aspects of colour are addressed directly in the colour chart-based Munsell notation that specifies the elements of perceived colour as value (lightness, from black to white on a scale of 0 to 10), chroma (degree of departure from gray toward pure chromatic colour), and hue (red, orange, yellow, green) McGuire (1992:1254). The author further mention that, in contrast, the instrumentally obtained coordinates, CIE 1931 (Y, x, y) or CIE 1976 (L*, a*, b*), provide information on lightness directly but require some computation to yield explicit measures of chroma and hue.CIE recommends the use of L*, a*, b*, where Delta L* is positive it indicate that the sample is lighter than standard, and if negative it would be darker than the standard. Figure:6below shows the plotting of L*, a* and b*. According to McGuire (1992:1254) L* ranges from black = zero to white =100, and on the horizontal axis positive a* indicates a hue of red-purple while negative a* ranges from bluish ï green. Furthermore, on the vertical axis positive b* indicates yellow and negative b* blue when negative it would be more blue or less yellow. Delta E* (Total Colour Difference) is based on L*, a*, b*, colour differences and was intended to be a single number metric for pass/fail decisions. According to Minolta (2007:22) ñæò Delta E* indicates the colour difference but not how the colours are different. The formula for calculating Delta E* (æE*) according to Minolta (2007:23) is:

$$\Delta E^* = \sqrt{\Delta a^{*2} + \Delta b^{*2} + \Delta L^{*2}}$$

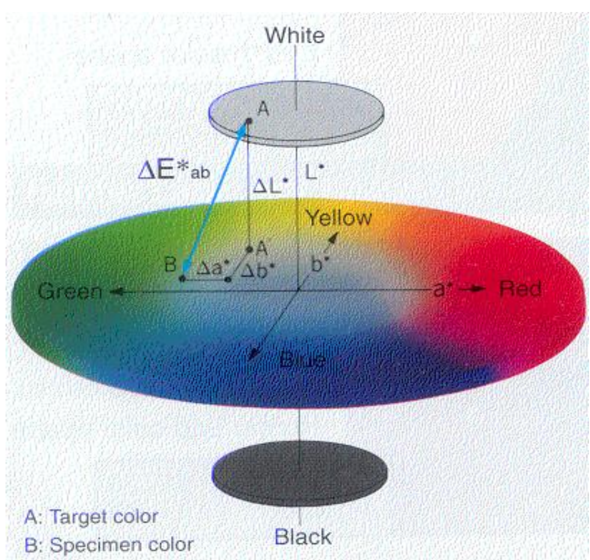

Figure 6: L*a*b* colour space and colour difference (ΔE*) (Minolta 2007:23)

CHAPTER 3

METHODOLOGY

3.1 RESEARCH STRATEGY

The purpose of this study is to determine water, energy and soil removal efficiency of a top and a front loader washing machine and identify the more efficient machine and more efficient program between the two machines and the chosen programs. The research was a controlled laboratory experiment. Research on water and energy efficiency of top and front loader machines have been done but without considering the soil removal efficiency. The research considered soil removal efficiency of the various programs in the given washing machines. Africa is developing and more households purchase washing machines as labour saving devices. The findings of the research would help to advice households to make the best purchase for their need as well as the environment.

A quantitative research strategy was used in this study, and controlled experiments were conducted in order to attain accurate data. Wise (2008:4) explains that, a quantitative research attempts to remain objective and neutral using standardized experimental methods and a reliance on mathematical and statistical models. Moreover, quantitative research answers questions about relationships among measurable variables with the purpose of explaining, predicting and controlling (Leedy&Ormrod 2010:94). This method was preferred for this research so that there will be a confirmation or disconfirmation of the hypotheses which are to be tested.

The study was designed as a factorial experiment to compare the following factors: soil removal, wash temperatures, wash duration, amount of water and energy consumption between the top and front loader washing machines. Leedy and Ormrod (2010:240) explain that, ñfactorial designs are whereby the researcher examines the effects of two or more independent variables in a single studyò, as the variables already stated.

3.2 Materials

3.2.1 Textile materials

Fabric 1: Soiled cotton fabric

Two types of soiled cotton fabric were used:

a) Fabric 1: CFT SM-04 2009 on PN-33 on a multi knitted cotton back. The sewn on stained patches were 2.5 cm by 2.5 cm. The 20 patches consisted of: CS-103 red wine, CS-12 blackcurrant, CS-BC-03 tea, C-BC-02 coffee, CN-11 white cotton, CS-28 rice starch, CS-26 corn starch, CS-6 dressing, CS-73 locust bean gum, CS-54 oatmeal/chocolate, CS-38 egg yolk/pigment, CS-01 blood, C-05 blood/milk/ink, CS-08 grass, CS-02 cocoa, C-10 pigment/oil/milk, C-02 olive oil/soot, CS-32 sebum bey, CS-17 make-up and CS-216 lipstick. The samplesare produced and supplied by Centre for Testmaterials BV. The Netherlands. The stains were of different colours making it easy for one to identify them well and measure colour differences using the colorimeter. For clarity the diagram has been included in the Appendix A.

b) Fabric 2: was a soiled cotton fabric C-09. The fabric soiled with pigment oil was obtained from Centre for Testmaterials. The fabric had received an ageing at elevated temperature treatment after the soil treatment. The fabric was cut into small samples of 5 cm by 10 cm after which they were overlocked to avoid fraying during laundering. These samples were then numbered for the process of random sampling.

Fabric 2: Cotton Filler cloths

Cotton fillers were used to fill the machines with 5 kg loads after the test samples were added. Even though the capacity of the washing machines was 8 kg, awash load of 5 kg was opted as it filled to capacity in the washing machine as more load over filled the washing machine hence affecting its performance. Cotton filler cloths were opted as they have been used by other researchers (AATCC manual 130-2010). These filler cloths were weighed before laundering and after laundering to see how much water is left in the filler cloths and determine the machines efficiency in removing water during spinning. Before using the filler cloths it was ensured that they were completely dry to avoid influencing the results in any way for the next wash cycle.

3.2.2 Laundering Machines

An 8 kg capacity top loader washing machine (T) and an 8.5 kg capacity front loader (F) from the same manufacturer were purchased. The machines will be coded as ñTòfor the Top loader and ñFòfor the front loader. Both washing machines were connected to the cold water tap but since the front loader has a heating element it was able to heat water to various temperatures. Both washing machines had an option of cold wash. For statistical analysis a figure was necessary so 20 ºC was used to represent cold wash in both washing machines.

Table 1: The description of the top loader as provided by the manufacturer

Power consumption	Wash	330 W	**Standard water level**	High	*57* ă
	Spin	240 W		Mild	*52ĕ*
Dimensions (mm)	W540×D560×H852(mm)			Low	*44*ă
Weight	35 kg			Extra low	*27ĕ*
Water pressure	0.05~0.78 mpa (0.5~8.0 kg f/cm^2)		**Water usage**	*150*ă	
Washing type	Stirring type		**Spin speed**	720 rpm	

Table 2: The descriptions of the front loader as provided by the manufacturer

Dimensions	W598×D600×H844(mm)			
Water pressure	50 kPa ~ 800 kPa			
Water volume	*64ℓ̆*			
Power consumption	Washing	220 V	150 W	
		240 V	150 W	
	Wash and heating	220 V	2000 W	
		240 V	2400 W	
	Spin 230 V	600 W	550 W	500 W
	Pumping	34 W		
Spin revolutions	Rpm	1400	1200	1000

3.2.3 Detergent

Non-phosphate reference detergent A also known as Non-phosphate reference detergent 2 ECE reference detergents 98 without optical brightening agent was used. The batch number of the detergent is CPC4402 and it was supplied James H.Heal& Co. LTD. The supplier recommends that it is suitable for use in procedures specified in ISO 105 C08, ISO 105 C09, ISO 6330:2000 and ISO 12138. For each cycle 60 grams of the detergent was used.

3.2.4 Energy consumption meter

The energy consumption was measured with a Wattmeter. The instrument measures the voltage and current of the apparatus in test. An analogue transfers the values to a digital converter. The product of the voltage and the current is expressed as the Watt value. An additional calculation is done to determine the watt-hour value (Wh).

3.2.5 Colour measurement

Soil show up as colour and soil removal can therefore be determined as colour difference from the soiled unlaundered fabric. Colour measurement was used to determine the difference between laundered fabrics with AATCC test method 135-1985 for instrumental colour measurement of textiles was used. A colorimeter was calibrated before conducting tests that was used to measure the colour difference. In each sample,5 different measurementswere taken for each different treatment thus 15 measurements for each treatment. To calculate the difference in shade CIE 1975 L*a*b* colour scale formula was used to get an average of æE* value, which is the colour difference of the washed stain compared to the unwashed stain. æE* value was used to show the colour difference of how the stain was removed, the higher the æE* the better the stain was cleaned.. For more explanation on colour difference, refer to page 30.

3.3 Procedure

3.3.1 Labelling of samples

Aged oil stained cotton samples (Fabric 2)were randomly selected labelled for each load. Samples were sewn to three separate pieces of the filler cloth for each wash cycle as the pieces were small and some could be trapped in the door of the washing machine for the whole wash cycle, this was done on fabric 2 described on paragraph 3.2.1 (b) above. As for Fabric 1 (described paragraph on 3.2.1 (a) above), out of the three randomly selected and labelled large piece of fabric with various stains sewn on it, two were washed in a separate wash cycles and the other set of stains washed in a different wash cycle to repeat the procedure. Refer to Appendix A for an elaborate description of fabric 1.

3.3.2 Laundering procedure

Laundering was done according to AATCC test method 130:2010 for soil release: oily stain release method. From each washing machine, the quick and daily wash programs were used to launder with the following temperatures: cold wash, 30 °C, 40 °C and 60 °C. The top loader only used cold wash temperature while the front loader used the rest of the temperatures mentioned.

3.3.3 Weighing

Wash loads of 5kg filler cloths with 3 randomly selected samples were used for each separate cycle. The filler clothes weighed 5kg in each program to be tested and 60 grams detergent was used. After a complete wash, the filler cloths were weighed and the reading recorded to determine how much water is left in the cloth and see which machine works better. This would indicate the efficiency in removal of water during the final spin. Before using the filler cotton cloths again it was ensured that they were completely dry.

3.3.4 Laundering

A machine programme was selected before any laundering took place. Before it starts operating the reading of the gadget measuring electricity was at zero and after the program completes washing readings for water, electricity, and duration of the program were recorded. Water consumption was measured using a 10 ǎ bucket and a measuring jar, this water was draw from the bigger container that could collect 170 ǎ Washing machine drained water inside this big container. For each wash program 3 repeats were done.

3.4 Statistical Analysis

Statistical analysis used the SPSS software for windows (Statistical Package for the Social Sciences) version 18.0. The statistical analysis was carried out using a factorial layout to determine the effect of water, energy and soil removal on the top loader and front loader washing machine. The Analysis of Variance (One way ANOVA)procedure was used to analyse laundry procedures that took place at cold wash between the two washing machines. While the Post Hoc (Turkey HSD) procedure was used to analyse the laundry procedures that took place at temperatures cold wash, 40 °C and 60 °C in the front loading washing machine only.

CHAPTER 4

RESULTS AND DISCUSSION

4.0 Introduction

The aim of the project was to evaluate the efficiency of a top loader and front loader washing machine with regard to water consumption, energy consumption and soil removal. The water was measured during washing and the energy used was measured in watt/hour (Wh). Soil removal was measured in colour difference determined with a colorimeter. Soiled and stained fabrics were washed in the machines. Soiled fabric used was soiled with oil and aged. The stains are categorized as follows: a) Hydrophobic Soils which includes - aged oil soiled cotton cloth, Lipstick, make up, sebum bey, olive oil/soot, pigment oil and dressing; b) Enzyme Sensitive soils which includes - Cocoa, grass, blood/milk/ink, blood, egg yolk, oatmeal/chocolate and locust bean gum -c) Particulates soils which includes; corn starch and rice starch and - d) Bleachable soils which includes; coffee, tea, blackcurrant and red wine. A white cotton piece of fabric was included in the set of stains to check for redeposition of stains during laundering. Only cold water was used to wash the soiled and stained samples in the top loader washing machine as it has no water heating system and was connected only to the cold water tapbut for the front loader; cold wash, 30 °C, 40 °C and 60 °C wash temperatures were used. Laundering was carried out in May and June which in Bloemfontein, South Africa is winter period, water temperatures could have been lower than 20 °C at room temperature especially in the morning, resulting in the use of more energy especially in the front loader as the machine had to heat water to the desired temperatures mentioned above. The results have been presented in graphs and tables to illustrate the effect of all these factors.

4.1 Water consumption by machines

Figure 7 below illustrates the difference in the amount of water used by both washing machines in both the quick and daily wash. The front loader quick wash program used 57ǎ and the daily wash program used 60ǎ which is almost the same amount of water. With the top loader the quick wash program used 114ǎ and daily washes 170ǎ of water. These results confirm the observation of Mead (2008:36) who states that, front loading washing machines are considered to be more water efficient than top loaders, as front load washing machines use an average of 60.6 ± 15.7 litre per cycle, whereas top load washing machines use 138.9 ± 23.9 litre per cycle. However, the amount of water used would differ according to models of machines and size of loads.

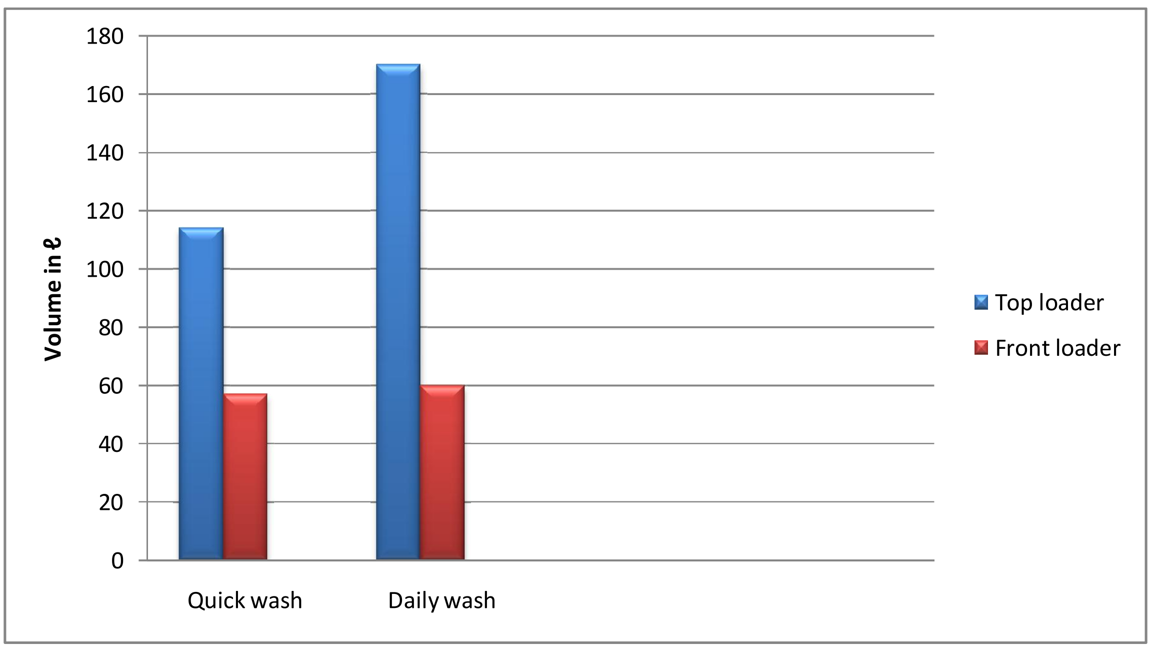

Figure 7: Water consumption of the top loader and front loader washing machines.

Table 3:Anova of the water consumption of the top and front loader washing machine.

t	Std. Deviation	Mean difference	Std. error	P-value
1.970E16	28	110.20000	.0000	.000

The statistical analysis indicated in table 3 show that there was a significant difference in the amount of water used between the two washing machines with the p-value < 0.05.

4.2 Energy consumption of washing machines

The front loader washing machine used more energy as compared to the top loader washing machine. The top loader was connected to the cold water tap only and cold water wash was used in laundering whilst the front loader was also connected to cold water but since it has a heating element that regulates water temperature up to 90 °C.

The results illustrated in figure 8show that, the top loader used very low energy, 43 Wh for quick wash and 75 Wh for daily wash as compared to the front loader which used 535 Wh for quick wash and 1344 Wh for daily wash at cold wash. The top loader used less energy as it was connected to the cold water tap and does not have a heating element as compared to the front loader which is connected to the cold water tap but does have a heating element which regulates water temperature up to 60 °C. The quick wash program in both machines used less energy as it takes a shorter time to wash than the daily wash. Both machines were of the same capacity and wash loads were of same weight, both these factors could not in any way have influenced the amount of energy used. As the graph indicates the front loader used more energy as temperatures rise in the quick wash and in the daily wash program. The difference in energy consumption between the quick and the daily program became less prominent with increase in wash temperature. These results differ from some reports in literature.

According to Yarra Valley Water (2010:1) front loaders are around twice as energy efficient as top loaders. The author explains that, electricity savings are mainly due to water efficiency, as less energy is required to heat a smaller amount of water. In the current study the top loader water was not heated. Mead (2008:23) also adds that, front loading or horizontal axis washers are more energy efficient than standard top loading or vertical axis machines. Palan & Dannels (1997:1) agree with the other authors that the front loader is an energy efficient washing machine as compared to the top loader when they state that, in Europe, high energy costs drove the market toward the front loading technology as it requires less water and energy to operate. The difference between the results obtained in this study and the reported literature might possibly be explained by differences in the power of the machine. Referring to chapter 3, table 1 and 2: top loader for wash program uses 330W and for spinning it uses 240W, whilst for the front loader, for wash and heating it uses 2400W and for spinning it uses 600W. This is a clear indication than the front loader uses more power than the top loader washing machine. The front loader quick wash though running for 28 minutes used more energy as compared to the top loader quick wash which runs for 29 minutes.

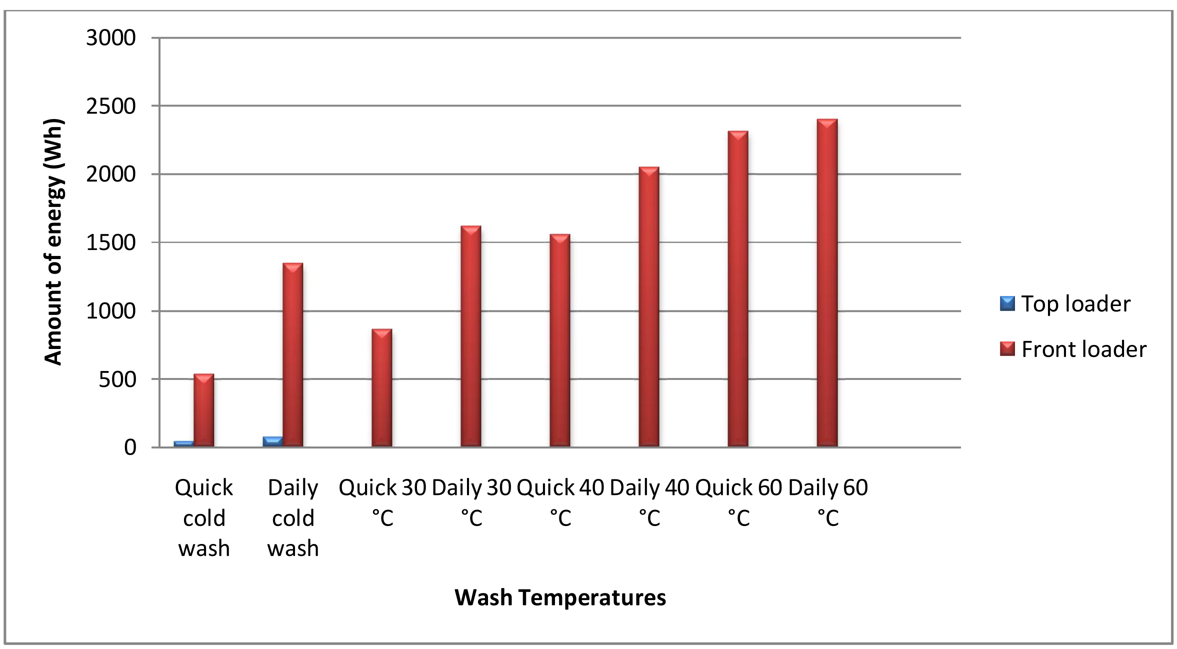

Figure 8: Energy consumption of the top loader and front washing machines

Table 4: Anova of the energy consumption of the top and front loader washing machine at cold wash.

	Std. deviation	Mean square	frequency	P-value
Quick wash	2	1.096E7	1911.028	.000
Daily wash	2	5179517.222	1388.522	.000

According to table 4 above there was a significant statistical difference in both the quick wash and daily wash program in the way energy was used by both washing machines as the p-value was <0.05.

4.3 Moisture retention in laundry after laundering in the top loader and front loader washing machines

Figure 9 below show that, the front loader quick wash removed water better with only 3.0kg of water still retained in the 5kg load that was washed and this means the cloths washed in the quick program will dry quicker as compared to the one's washed in the top loader quick wash which had 3.8kg water still retained. It will save energy in the drying process. For the daily program the top loader had 3.6kg water in the laundry whilst in the front loader 3.1kg of water was still on the laundry. The quick wash program removed water from clothes better than the daily wash program of the top loader machine. These results confirmed results reported in literature.

According to Palan & Dannels (1997:1) front loading machines spin the laundry faster and remove more of the moisture content resulting in a shorter dryer time for the load. Bluejay (2010:2) agrees stating that, front-load washers squeeze more of the water out of your cloths, hence less time and energy to dry laundry. Austin *et al.* (2007:30) also add that, front loader machines use less water and high spin speeds during the rinse cycle causes cloths to dry more quickly.

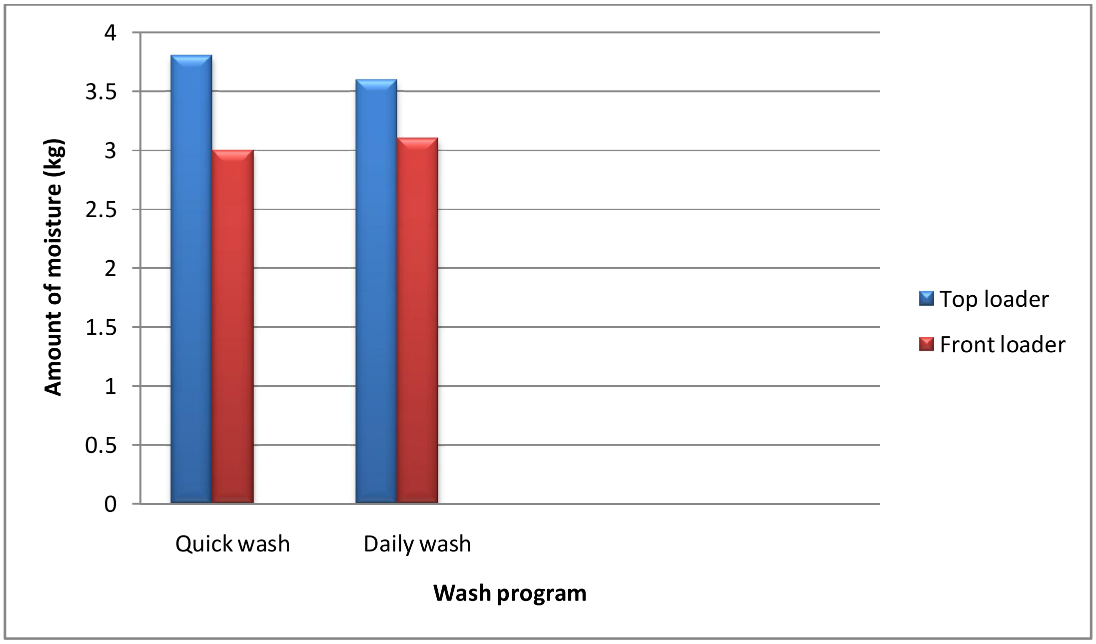

Figure 9: Moisture retention of the load in the top and front loader washing machines.

Table 5: Anova of the difference in water retained in laundry after wash in the top and front loader washing machines.

	t	Std. deviation	Mean difference	Std. error	P-value
Quick wash	9.28E15	28	.80000	.00000	.000
Daily wash	2.691E15	28	.50000	.00000	.000

The statistical analysis clearly indicates that there was a significant difference on the moisture retained, with p-value <0.05 in both the quick and daily programs of the top and front loader washing machines.

4.4 Hydrophobic soils

According to Kissa&Cuttler (1987:7) the properties of oily soils that are the most important from the detergency point of view are their viscosity, polarity and solubility in detergent solutions at the wash temperature. These authors explain that, the removal of soils is facilitated by the low viscosity of the soil, the polarity of the soil affects adhesion of the soil on fibres and interaction with the detergent. Johansson & Somasundaran (2007:65) add that, hydrophobic soils have low energy and spread well on the fabric surface, these stains are not miscible with water and their removal need the presence of surfactants in the washing water.

4.4.1 Aged oil soiled cloth

Figure 10 show the results of soil removed from cotton fabric that was soiled by oil and aged, which was washed in cold water in the top and front loader (cold wash) washing machine. The results show that the soil was removed better (82.7 æE) when washed in the front loader with the daily program which washes for a longer time and it was removed least (78.9 æE) in the top loader quick wash program. According to literature, aging of oily soils makes them difficult to remove in cold water as they turn yellow into stains on fabrics and less oil is been removed by laundering (Chi &Obendorf 2001:35). Hence it is better to wash in warm water as the fat dissolves easier than in cold water making the oil to be removed better.

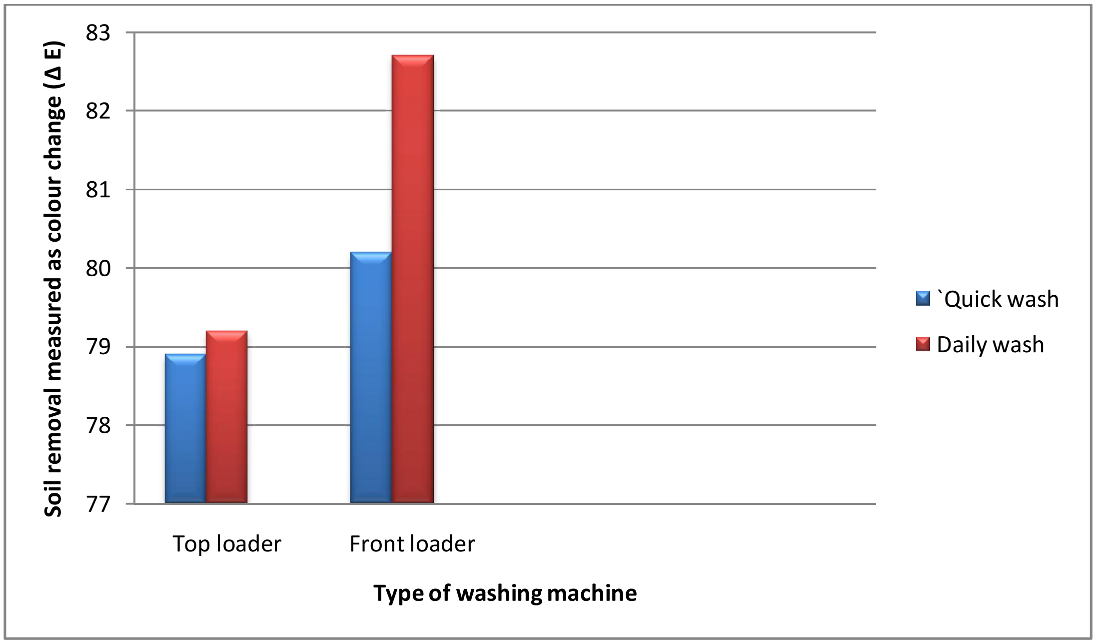

Figure 10: Soil removed from aged oil soiled fabric in the top loader and front loader washing machine at cold wash.

Table 6: Anova of soil removed from aged oil soiled fabric washed in the top loader and front loader cold wash.

	t	Std. deviation	Mean difference	Std. error	P-value
Quick wash	-4.614	28	-1.76000	.38144	.000
Daily wash	-6.505	28	-3.49333	.53698	.000

The statistical analysis in table 6 above shows that, there was a significant difference on the removal of the soil between the washing programs with p-value <0.05.

The soil removal from the oil soiled cotton fabric at cold wash, 30 °C, 40 °C and 60 °C in figure 11 below show that, the higher the temperature the better the stain was removed as at 60 °C, where the colour difference from the washed sample was 84.6 æE in the daily program and it was not much of a difference with the quick wash at the same temperature which thecolour difference was at 83.4 ∆E. The lowest level of soil removal (80.2 ∆E) was experienced at cold wash with the quick wash program. When taking a closer look comparing the performance of the quick and daily wash, the daily wash removed the oil soil much better. These results were not surprising as the program wash longer which mean longer agitation energy added. The results confirm the observation of Cireli*et al.* (2004:111) that, effective soil removal degrees are obtained when laundering at high temperatures and long washing times. It is also evident that the difference in soil removal between the quick and daily program became less prominent when the temperature rise.

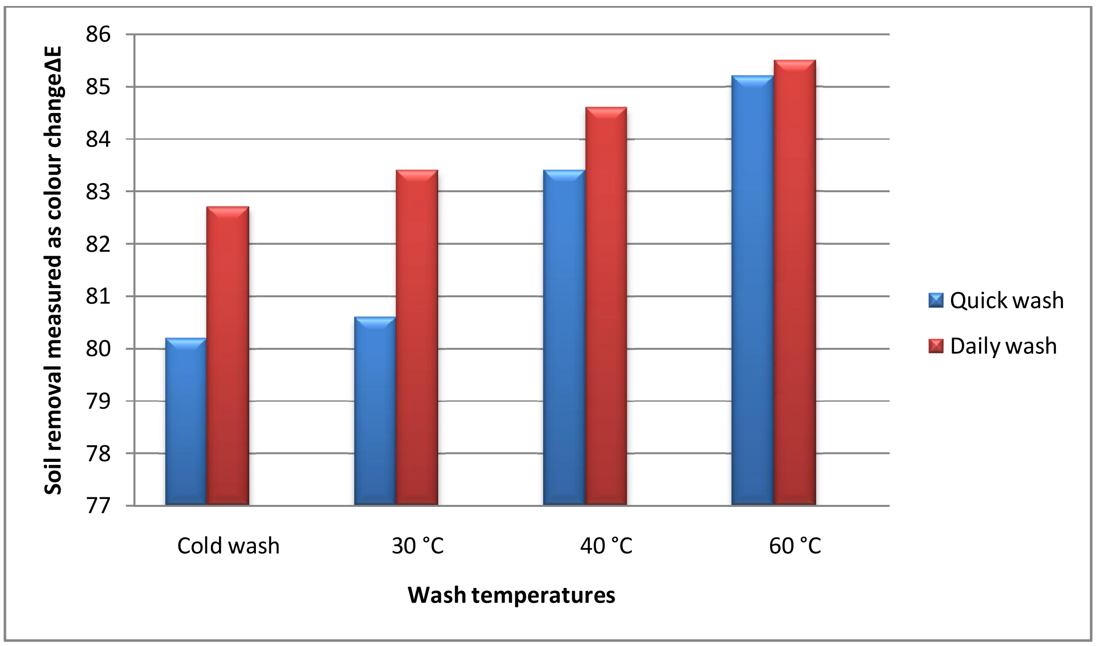

Figure 11: Soil removed from an aged oil soiled cotton fabric in the front loader washing machine at cold wash, 30 °C, 40 °C and 60 °C.

Table 7: Post hoc test on soil removed from an aged oil soiled cotton fabric in the front loader washing machine at cold wash, 30 °C, 40 °C and 60 °C.

	Water temp.	Water temp.	Mean difference	Std. error	P-value
Quick wash	Cold wash	30 °C	.14000	.23843	.936
		40 °C	-2.64667*	.23843	.000
		60 °C	-4.45333*	.23843	.000
	30 °C	Cold wash	-.14000	.23843	.936
		40 °C	-2.78667*	.23843	.000
		60 °C	-4.59333*	.23843	.000
	40 °C	Cold wash	2.64667*	.23843	.000
		30 °C	2.78667*	.23843	.000
		60 °C	-1.80667*	.23843	.000
	60 °C	Cold wash	4.45333*	.23843	.000
		30 °C	4.59333*	.23843	.000
		60 °C	1.80667*	.23843	.000
Daily wash	Cold wash	30 °C	-.72000	.31706	.117
		40 °C	-1.92667*	.31706	.000
		60 °C	-2.80667*	.31706	.000
	30 °C	Cold wash	.72000	.31706	.117
		40 °C	-1.20667*	.31706	.002
		60 °C	-2.08667*	.31706	.000
	40 °C	Cold wash	1.92667*	.31706	.000
		30 °C	1.20667*	.31706	.002
		60 °C	-.88000*	.31706	.037
	60 °C	Cold wash	2.80667*	.31706	.000
		30 °C	2.08667*	.31706	.000
		60 °C	.88000*	.31706	.037

As indicated by table 7 above, there was not a significant difference between quick wash temperatures cold wash and 30 °C as p-value was at >0.05 (.936) in the quick wash program. However in other temperature comparisons there was a statistical difference as p-value was <0.05. In the daily wash program, it was noted that there were no statistical difference between the following wash temperatures: cold wash and 30 °C, and 40 °C and 60 °C as the p-value was > 0.05.

A stain is defined as a local deposit of soil or discoloration on a substrate that exhibits some degree of resistance to removal as by laundering or dry cleaning (AATCC technical manual 2010:207). A variety of stains were used in this project to evaluate the efficiency of the top and front loader washing machines for the removal of the stains in the quick wash and daily wash programs at different wash temperatures. Most of the stains were partially removed by the top and front loader washing machines at the different temperatures that they were subjected to.

4.4.2 Lipstick stain

Lipstick stain as indicated in figure 12 below was difficult to remove especially at lower temperatures using the quick wash program. The stain contains oil, wax and pigment creating a hydrophobic stain (Goins 2010:1) not miscible with water and they are more difficult to remove in cold water than in hot water. The stain was removed best in the front loader daily wash program where 87.3 æE colour difference was observed and least removed in the top loader where the colour difference was 82 æE. There was a definite improvement in the stain removal with increase in wash temperature in the front loading washing machine and the daily wash program had better stain removal than the quick wash program at every temperature.

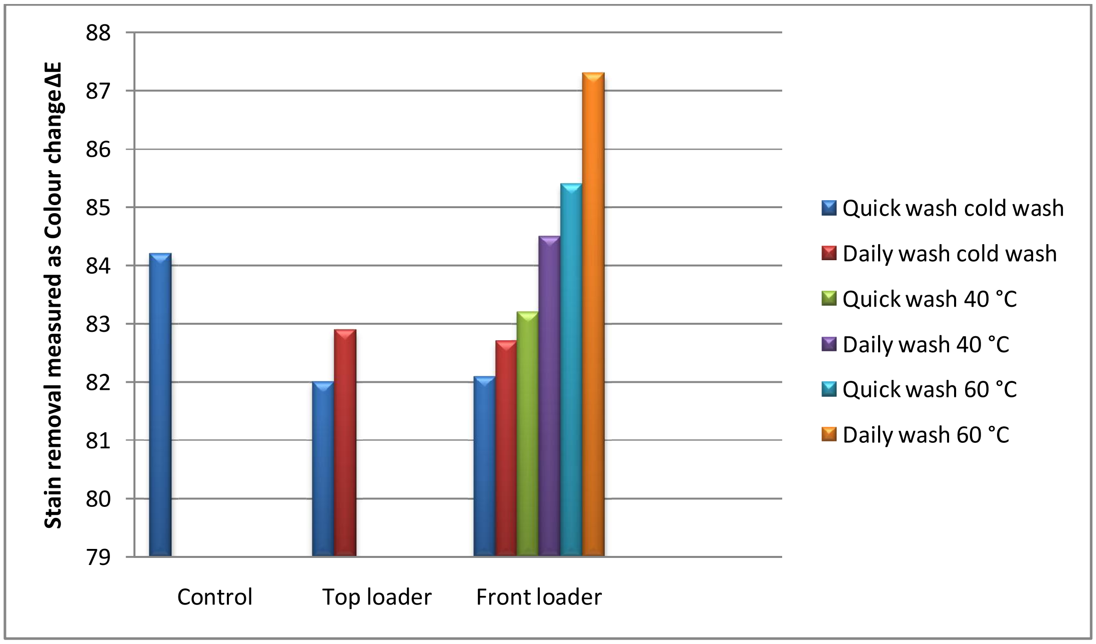

Figure 12: Lipstick stain removal in the top loader cold wash and the front loader at cold wash, 40 °C and 60 °C.

Table 8: Anova of how lipstick stain was removed at cold wash in the front loader and top loader.

	Std. deviation	Mean square	frequency	P-value
Quick wash	2	42.193	77.814	.000
Daily wash	2	80.847	307.051	.000

According to table 8 above, there was a significant statistical difference between the removal of the lipstick stain at cold wash in both the quick and daily wash programs of the top loader and front loader washing machines as the p-value was <0.05.

Table 9: Post hoc test comparing lipstick stain colour difference at cold wash, 40 °C and 60 °C in the front loader washing machine.

	Water temp.	Water temp.	Mean difference	Std. error	P-value
Quick wash	Cold wash	40 °C	-1.09000*	.30062	.002
		60 °C	-3.30667*	.26888	.000
	40 °C	Cold wash	1.09000*	.30062	.002
		60 °C	-2.21667*	.30062	.000
	60 °C	Cold wash	3.30667*	.26888	.000
		40 °C	2.21667*	.30062	.000
Daily wash	Cold wash	40 °C	-1.80000*	.18737	.000
		60 °C	-4.60667*	.18737	.000
	40 °C	Cold wash	1.80000*	.18737	.000
		60 °C	-2.80667*	.18737	.000
	60 °C	Cold wash	4.60667*	.18737	.000
		40 °C	2.80667*	.18737	.000

From the table 9 above, post hoc test compared all the wash temperature against one another and there was a statistical difference on the lipstick stain removal at difference temperatures in the front loader washing machine as the p-value was <0.05.

4.4.3 Make up stain

Make-up stain was well removed by both machines (Fig. 13). The front loader removed the stain better in both its quick and daily programs. At cold wash there was little difference in the removal of make up between the front loader and top loader washing machines when using the daily wash programs of the machines. When using the quick wash programs at cold wash the front loader removed the make-up stain better with the daily program at cold wash, there was no difference between the top and front loader. Better make-up stain removal was observed at the higher temperatures in the front loader machine. The daily wash program was better in make-up stain removal than the quick wash program at every temperature. The daily wash program was at 40 °C even better in make-up stain removal than the quick wash program at 60 °C. The best results in make-up stain removal were achieved with the daily wash program at 60 °C. The results are in agreement with results reported in literature that make-up is difficult to remove in cold water. According to Ylisela (2011:1) make-up stain contains oil in it making hydrophobic and not miscible with water and they are more difficult to remove in cold water than in warm to hot water.

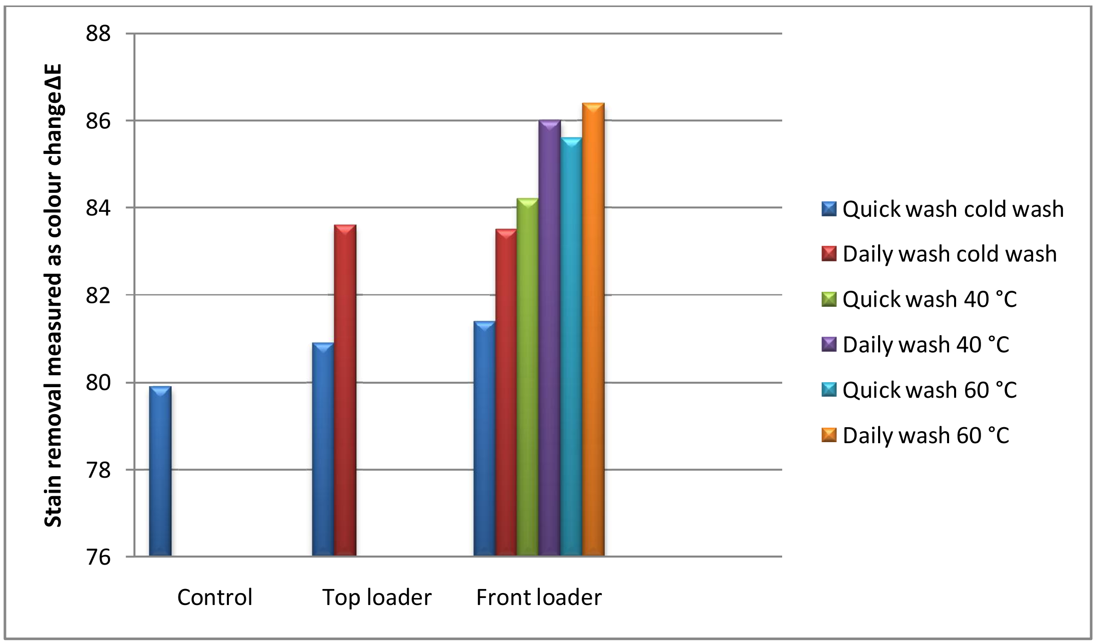

Figure 13: Make-up stain removal in the top loader cold wash and the front loader at cold wash, 40 °C and 60 °C.

Table 10: Anova of how make-up stain was removed at cold wash in the front loader and top loader.

	Std. deviation	Mean square	frequency	P-value
Quick wash	2	66.026	73.780	.000
Daily wash	2	35.440	201.002	.000

Table 10 above shows that there was a significant statistical difference between the quick wash and daily wash programs of the top and front loader washing machines as the p-value was <0.05.

Table 11: Post hoc test comparing make-up stain colour difference at cold wash, 40 °C and 60 °C temperatures in the front loader washing machine.

	Water temp.	Water temp.	Mean difference	Std. error	P-value
Quick wash	Cold wash	40 °C	-2.82333*	.38620	.000
		60 °C	-4.12667*	.34543	.000
	40 °C	Cold wash	2.82333*	.38620	.000
		60 °C	-1.30333*	.38620	.005
	60 °C	Cold wash	4.12667*	.34543	.000
		40 °C	1.30333*	.38620	.005
Daily wash	Cold wash	40 °C	-2.46000*	.15333	.000
		60 °C	-2.82667*	.15333	.000
	40 °C	Cold wash	2.46000*	.15333	.000
		60 °C	-.36667	.15333	.055
	60 °C	Cold wash	2.82667*	.15333	.000
		40 °C	.36667	.15333	.055

The post hoc test in table 11 above shows that there was a statistical difference between the make-up stain removal at the different temperatures in the quick wash program of the front loader washing machine with p-value < 0.05. In the daily wash program of the front loader washing machine there was a significant difference on the make-up stain removal between cold wash and 40 °C and between cold wash and 60 °C but not between 40 °C and 60 °C.

4.4.4 Sebum bey stain

The results shown in fig. 14 indicate that the daily wash program was more successful in removing the sebum bey stains than the quick wash programs of both the top and front loader washing machines at cold wash. The sebum bey stain removal increased with increase in temperature with the daily wash program more efficient at removal of the stain at cold wash, 40 °C and 60 °C then the quick wash program. The difference in efficiency in stain removal between the daily wash program and quick wash program became less prominent at high temperatures with very little difference at 60 °C. Sebum contain oil and also medium chain fatty acids in the form of medium chain triglycerides (Fife 2001:1) and oily stains are more difficult to remove in cold water (Ylisela 2011:1).

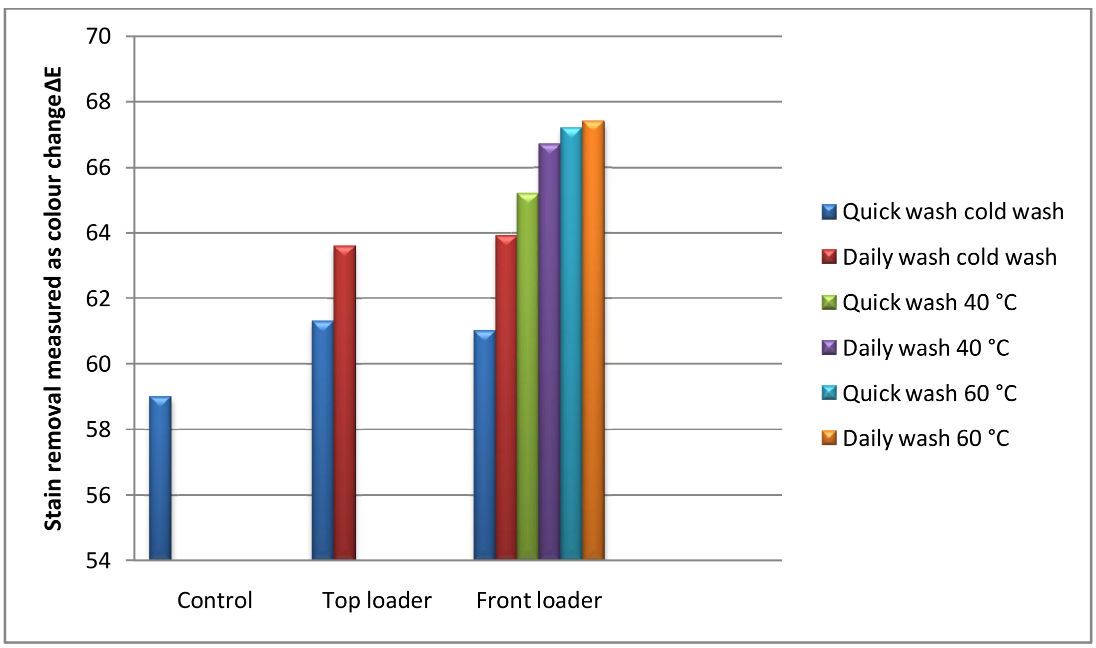

Figure 14: Sebum bey stain removal in the top loader cold wash and at cold wash, 40 °C and 60 °C in the front loader.

Table 12: Anova of how sebum bey stain was removed at cold wash in the front loader and top loader.

	Std. deviation	Mean square	frequency	P-value
Quick wash	2	145.952	572.949	.000
Daily wash	2	105.862	52.931	.000

Table 12 above show that there was a significant statistical difference on sebum bey stain removal at cold wash as the p-value was less than <0.05 in both the top loader and front loader washing machines at both quick wash and daily wash programs.

Table 13: Post hoc test comparing sebum bey stain colour difference at cold wash, 40 °C and 60 °C wash temperatures in the front loader washing machines.

	Water temp.	Water temp.	Mean difference	Std. error	P-value
Quick wash	Cold wash	40 °C	-4.24000*	.20605	.000
		60 °C	-6.12667*	.18430	.000
	40 °C	Cold wash	4.24000*	.20605	.000
		60 °C	-1.88667*	.20605	.000
	60 °C	Cold wash	6.12667*	.18430	.000
		40 °C	1.88667*	.20605	.000
Daily wash	Cold wash	40 °C	-2.83333*	.23132	.000
		60 °C	-3.55333*	.23132	.000
	40 °C	Cold wash	2.83333*	.23132	.000
		60 °C	-.72000*	.23132	.009
	60 °C	Cold wash	3.55333*	.23132	.000
		40 °C	.72000*	.23132	.009

According to table 13, the daily wash program between did show a statistical difference between the sebum bey stain removal at all temperature comparisons as the p-values smaller than 0.05.

4.4.5 Olive oil/soot stain

Figure 15 show the results of the olive/soot stain washed in the top loader and the front loader washing machine. The results show little difference in the stain removal efficiency of the top loader and the front loader at cold wash with a colour difference of 60.5 æE with the top loader and 59.8 æE reached with the front loader in the quick wash program and 64.9 æE and 64.8 æE with the daily program. According to Hsin-Yi (2010:1) stains from soot are caused by carbon particles and result as a combination of a local source of carbon and air movement that causes the carbon particles to spread through the fibres, making the removal of the stain difficult.

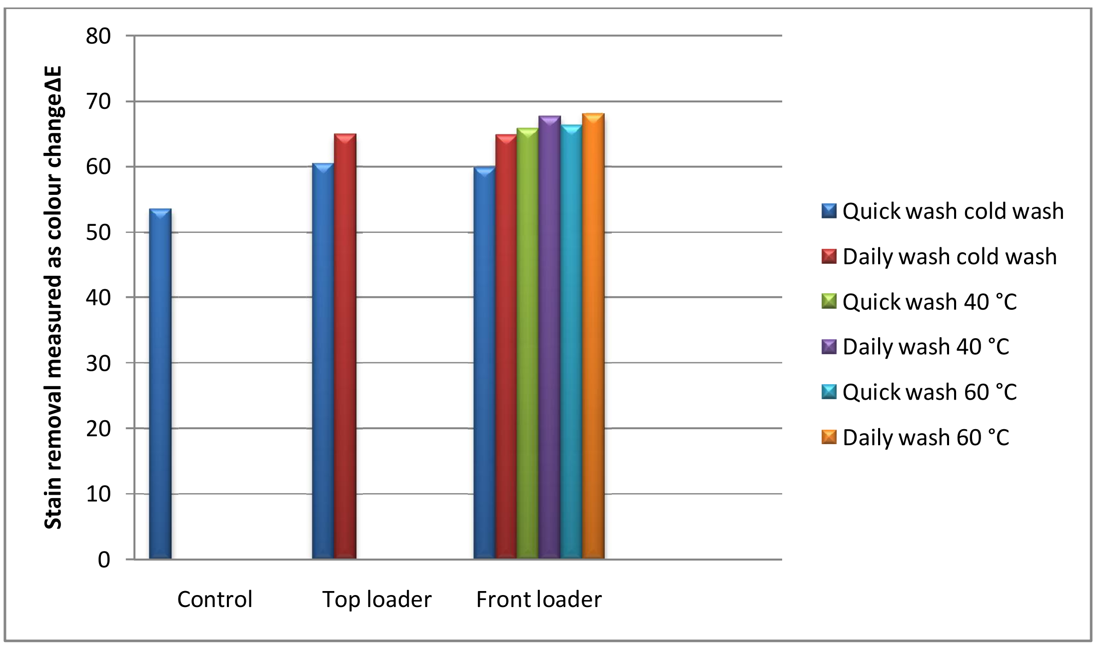

Figure 15: Olive oil/soot stain removal in the top loader cold wash and front loader at cold wash, 40 °C and 60 °C.

Table 14: Anova of how olive oil/soot stain was removed at cold wash in the front loader and top loader.

	Std. deviation	Mean square	frequency	P-value
Quick wash	2	188.984	49.365	.000
Daily wash	2	44.700	54.901	.000

Table 14 above show that there was a statistical difference in colour as the p-value was less than <0.05 in both the quick and daily wash program of both top and front loader washing machines.

Table 15: Post hoc test comparing olive oil/soot stain colour difference at cold wash, 40 °C and 60 °C in the front loader washing machine.

	Water temp.	Water temp.	Mean difference	Std. error	P-value
Quick wash	Cold wash	40 °C	-5.99333*	.79878	.000
		60 °C	-6.56000*	.71445	.000
	40 °C	Cold wash	5.99333*	.79878	.000
		60 °C	-.56667	.79878	.759
	60 °C	Cold wash	6.56000*	.71445	.000
		40 °C	.56667	.79878	.759
Daily wash	Cold wash	40 °C	-2.73333*	.32948	.000
		60 °C	-3.19333*	.32948	.000
	40 °C	Cold wash	2.73333*	.32948	.000
		60 °C	-.46000	.32948	.352
	60 °C	Cold wash	3.19333*	.32948	.000
		40 °C	.46000	.32948	.352

According to table 15, in both the quick and daily programs there was no statistical difference as p-value was 0.759 in the quick program and 0.352 in the daily wash programs between temperature 40 °C and 60 °C. Whilst for the other temperature combinations there was significant statistical difference as the p-values was<0.05.

4.4.6 Pigment oil stain

Fig. 16 clearly shows that the pigment oil stains were removed well at high temperatures of 40 °C and 60 °C. As indicated in the literature on oil stain is a hydrophobic stain which is difficult to remove in cold water and needs longer time to wash for the stain to be removed well. At quick wash 40 °C the difference from the washed sample was 78.9 æE and with the daily wash at 60 °C it was 79.1 æE, a relatively small difference. The stain was least removed by the top loader in the quick wash program showing a difference of 76.4 æE at cold wash. Since the wash time is shorter and the water was cold in the top loader it is not surprising that the stain was least removed. The results also indicate that the stain was removed better in the front loader wash programs than in the top loader wash programs.

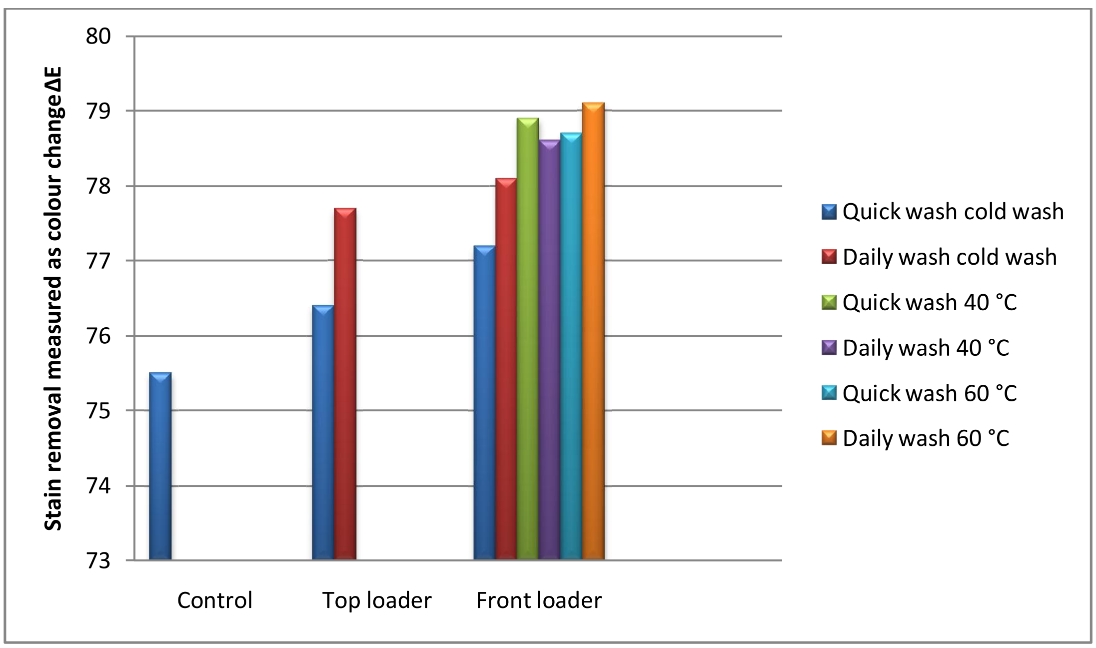

Figure 16: Pigment oil stain removal in the top loader cold wash and at cold wash, 40 °C and 60 °C in the front loader washing machine.

Table 16: Anova of how pigment oil stain was removed at cold wash in the front loader and top loader.

	Std. deviation	Mean square	frequency	P-value
Quick wash	2	12.409	27.293	.000
Daily wash	2	3.908	11.661	.000

Table 16 above show that there was a statistical difference as the p-value was less than <0.05 in both the quick wash and daily wash of the top and front loader washing machine.

Table 17: Post hoc test comparing pigment oil stain colour difference at cold wash, 40 °C and 60 °C in the front loader washing machine.

	Water temp.	Water temp.	Mean difference	Std. error	P-value
Quick wash	Cold wash	40 °C	-1.72333*	.27527	.000
		60 °C	-1.55333*	.24621	.000
	40 °C	Cold wash	1.72333*	.27527	.000
		60 °C	.17000	.27527	.811
	60 °C	Cold wash	1.55333*	.24621	.000
		40 °C	-.17000	.27527	.811
Daily wash	Cold wash	40 °C	-.54667*	.21139	.035
		60 °C	-1.02000*	.21139	.000
	40 °C	Cold wash	.54667*	.21139	.035
		60 °C	-.47333	.21139	.076
	60 °C	Cold wash	1.02000*	.21139	.000
		40 °C	.47333	.21139	.076

According to table 17, in the quick programs between temperature 40 °C and 60 °C there was no statistical difference in the removal of pigment oil stain as the p-value was 0.811, in the daily program there was also no significant difference in pigment oil stain removal between 60 °C and 40 °C where the p-value was 0.76. A significant colour difference was obtained between other wash temperature combinations which their p-value was <0.05.

4.4.7 Dressing stain

Figure 17 show the results of stain removal of dressing stain. The results show that the dressing stain removal improved with increase in temperature. The lowest results were obtained in the top loader quick wash where a colour difference of 74.7 ∆E was observed. At the low temperature the difference in stain removal between the quick and daily wash programs was more prominent than at high temperatures. Dressing contains oil making the stain difficult to remove as it is hydrophobic. According to literature, oily stains are difficult to remove in cold water Ylisela (2011:1), making the stain removal better as the temperature rises and when washing takes longer. The results have proven that, dressing stain was removed best in the front loader daily wash program, where a colour difference at 80.5 ∆E was observed.

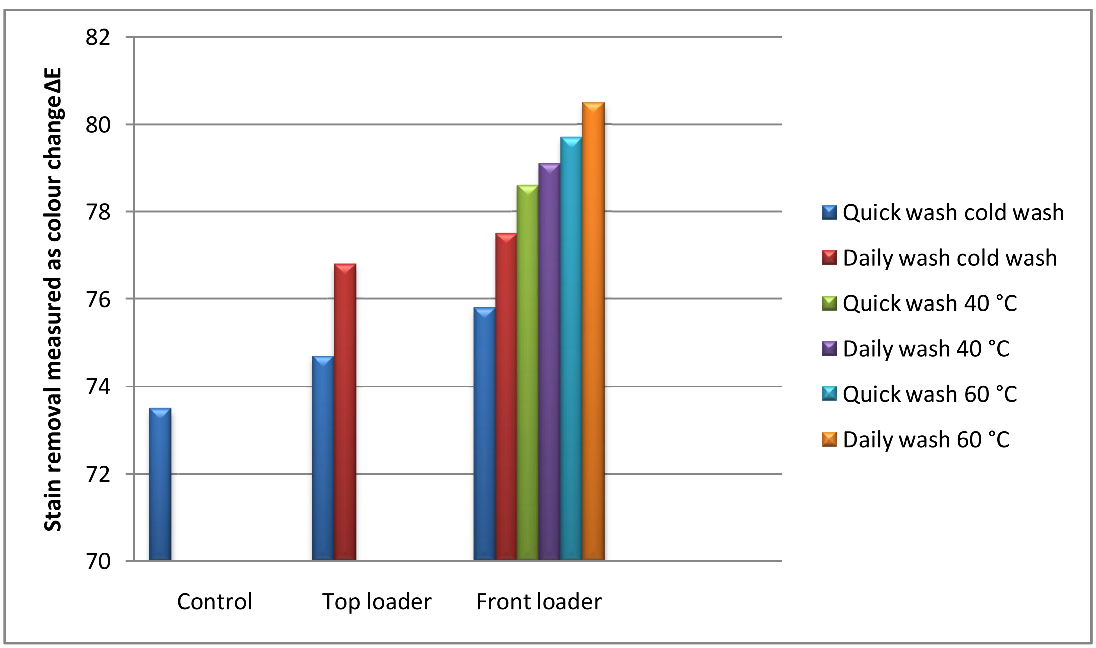

Figure 17: Dressing stain removal in the top loader cold wash and the front loader at cold wash, 40 °C and 60 °C.

Table 18: Anova of how dressing stain was removed at cold wash in the front loader and top loader.

	Std. deviation	Mean square	frequency	P-value
Quick wash	2	58.476	98.956	.000
Daily wash	2	33.976	148.853	.000

Table 18 above show that there was a statistical difference on the colour of dressing stain as the p-value was less than <0.05 in both the quick and daily wash programs of the front loader and top loader washing machines.

Table 19: Post hoc test comparing dressing stain colour difference at cold wash, 40 °C and 60 °C in the front loader washing machine.

	Water temp.	Water temp.	Mean difference	Std. error	P-value
Quick wash	Cold wash	40 °C	-2.79000*	.31482	.000
		60 °C	-3.85333*	.28158	.000
	40 °C	Cold wash	2.79000*	.31482	.000
		60 °C	-1.06333*	.31482	.005
	60 °C	Cold wash	3.85333*	.28158	.000
		40 °C	1.06333*	.31482	.005
Daily wash	Cold wash	40 °C	-1.62667*	.17445	.000
		60 °C	-3.00667*	.17445	.000
	40 °C	Cold wash	1.62667*	.17445	.000
		60 °C	-1.38000*	.17445	.000
	60 °C	Cold wash	3.00667*	.17445	.000
		40 °C	1.38000*	.17445	.000

According to table 19, in all the wash temperatures there has been a statistical difference in both the quick and daily was programs of the front loader washing machine as the p-value was <0.05.

4.5 Enzyme sensitive stains

4.5.1 Cocoa stain

According to Center for test materials B.V (2008/2009:24) cocoa test for general detergency and proteolytic enzyme activity. The results in Fig. 18 indicate that cocoa stain was only removed when it was washed in the top loader daily program with a colour difference of 73.7 æE. In all the other washes the stain got even worse than the control. The cocoa test for general detergency and proteolytic enzyme activity explains that, mere washing of the stain may not remove the cocoa stain as cocoa has chromophores which may require bleach (Puġiĺ *et al.* 2007:407). The stain was cleaned better in the daily wash of the top loader as more water was used in rinses.

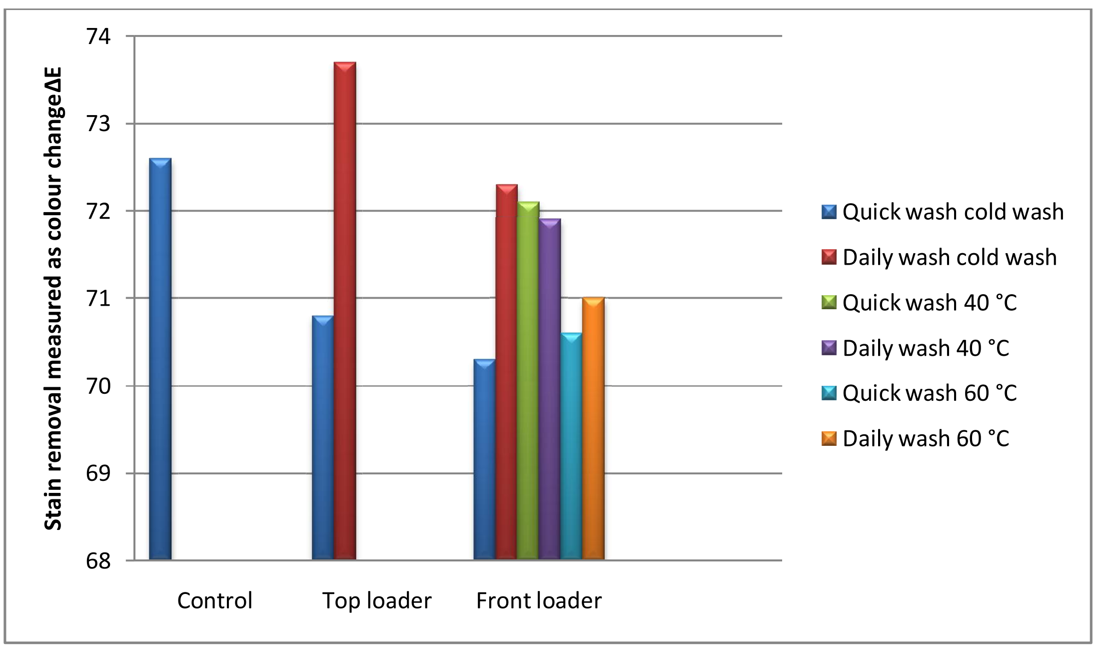

Figure 18: Cocoa stain removal in the top loader cold wash and front loader machine at cold wash, 40 °C and 60 °C.

Table 20: Anova of how cocoa stain was removed at cold wash in the front loader and top loader.

	Std. deviation	Mean square	frequency	P-value
Quick wash	2	9.988	8.361	.001
Daily wash	2	6.244	21.373	.000

Table 20 above show that there was a significant statistical difference on colour from the washed sample on the removal of cocoa stain as the p-value was less than <0.05 in both the daily and quick wash programs of the top and front loader washing machines.

Table 21: Post hoc test comparing cocoa stain colour difference at cold wash, 40 °C and 60 °C in the front loader washing machine.

	Water temp.	Water temp.	Mean difference	Std. error	P-value
Quick wash	Cold wash	40 °C	-1.75000*	.44622	.001
		60 °C	-.28667	.39911	.754
	40 °C	Cold wash	1.75000*	.44622	.001
		60 °C	1.46333*	.44622	.006
	60 °C	Cold wash	.28667	.39911	.754
		40 °C	-1.46333*	.44622	.006
Daily wash	Cold wash	40 °C	.42000	.19737	.096
		60 °C	1.26667*	.19737	.000
	40 °C	Cold wash	-.42000	.19737	.096
		60 °C	.84667*	.19737	.000
	60 °C	Cold wash	-1.26667*	.19737	.000
		40 °C	-.84667*	.19737	.000

According to table 21 above, there was no significant statistical difference in colour between temperatures cold wash and 60 °C in the quick wash program as the p-value was greater than 0.05. Again in the daily it was noted that, there was no significant statistical difference in colour between wash temperatures cold wash and 40 °C. In the other temperature combinations there were a significant difference in colour on the removal of cocoa stain as the p-value was <0.05.

4.5.2 Grass stain

Grass stains are designed to test for proteolytic activity and considered to be one of the most difficult stains to remove (Center for Testmaterials 2008/2009:24). Grass stain was partly removed by both washing machines at different levels but it was best removed washed in the front loader daily wash program at 60 °C and and least removed with the quick wash program at 40 °C. The daily wash program was very effective in removal of the grass stain at every temperature in both the top and front loader washing machine. Figure 19 also indicate that, the grass stain was removed at the same level at cold wash temperature in both the top loader and front loader. According to literature grass stain can be difficult to remove because grass stains can be a mixture of protein and other organic matter and mixed with grassesô juices including chlorophyll and other relatively stable pigmented compounds (xanthophylls and carotenoids), and once present such material closely binds to the natural fibres making the removal difficult (Corina 2011:1). The author further warns that, ammonia degreases and alkaline detergents should not be used to eliminate grass stains as it would permanently set the stain.

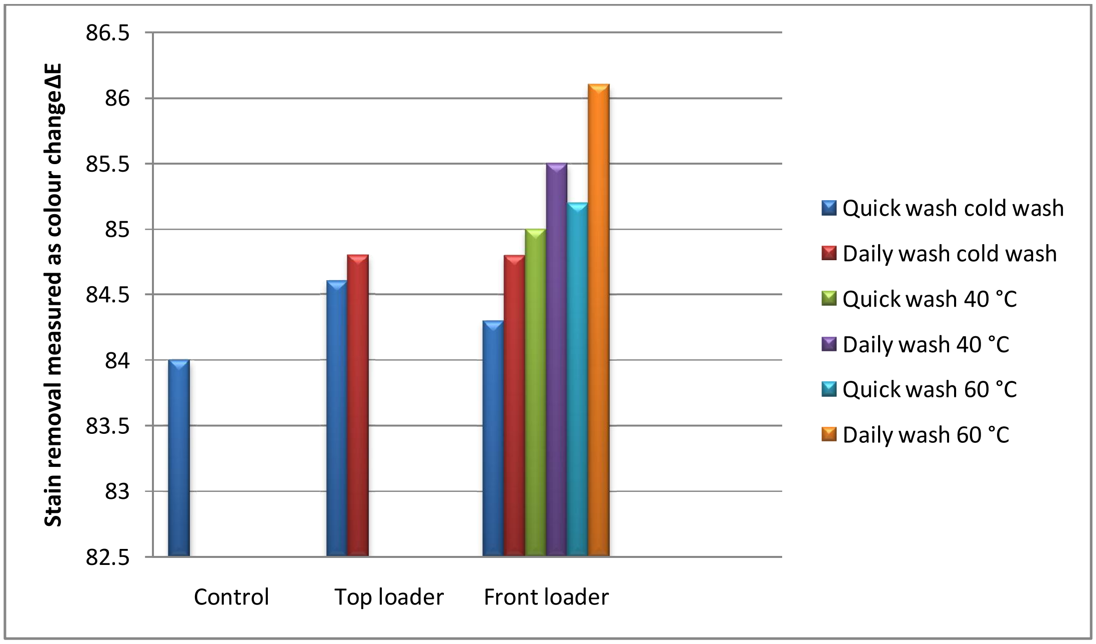

Figure 19: Grass stain removal in the top loader cold wash and front loader at cold wash, 40 °C and 60 °C.

Table 22: Anova of how grass stain was removed at cold wash in the front loader and top loader washing machine.

	Std. deviation	Mean square	frequency	P-value
Quick wash	2	3.222	16.754	.000
Daily wash	2	6.414	71.690	.000

Table 22 above show that there was a significant statistical difference in colour of the grass stain removal as the p-value was less than <0.05 in both the wash programs quick and daily wash of the top and front loader washing machines.

Table 23: Post hoc test comparing grass stain colour difference at cold wash, 40 °C and 60 °C in the front loader washing machine.

	Water temp.	Water temp.	Mean difference	Std. error	P-value
Quick wash	Cold wash	40 °C	-.71333*	.17902	.001
		60 °C	-.88667*	.16012	.000
	40 °C	Cold wash	.71333*	.17902	.001
		60 °C	-.17333	.17902	.601
	60 °C	Cold wash	.88667*	.16012	.000
		40 °C	.17333	.17902	.601
Daily wash	Cold wash	40 °C	-.70000*	.10929	.000
		60 °C	-1.30667*	.10929	.000
	40 °C	Cold wash	.70000*	.10929	.000
		60 °C	-.60667*	.10929	.000
	60 °C	Cold wash	1.30667*	.10929	.000
		40 °C	.60667*	.10929	.000

According to table 23, in the daily wash program there was a significant colour difference on the removal of grass stain as the p-value was <0.05. Whilst in the quick wash it is was noted that, there was no significant statistical difference in colour between wash temperature 40 °C and 60 °C as the p-value was greater than 0.05.

4.5.3 Blood/milk/ink stain

Blood/milk/ink stain are designed to test for proteolytic activity and considered to be one of the most difficult stains to remove (Center for testmaterials 2008/2009:24). Figure 20 below show that blood/milk/ink stains as compared to the control were partly removed by both washing machines at a similar rate even though better results were obtained in the front loader. At the low temperature (cold wash) the daily wash cycle was more efficient in removal of the stain than the quick wash cycle, at 40 °C and 60 °C the difference in stain removal was very small in both the quick and the daily wash cycles. According to literature,proteins do coagulate when in contact with heat, if blood stain is washed with hot water it will get fixed into the fabric hence the need to wash it in cold water (Corina 2011:1). However this is in contrary to the results as the stain removed somewhat better at higher temperature, but without difference between 40 °C and 60 °C. This may be due to the fact that the stain was a combination of blood, milk and ink which altered the properties of the stain all together.

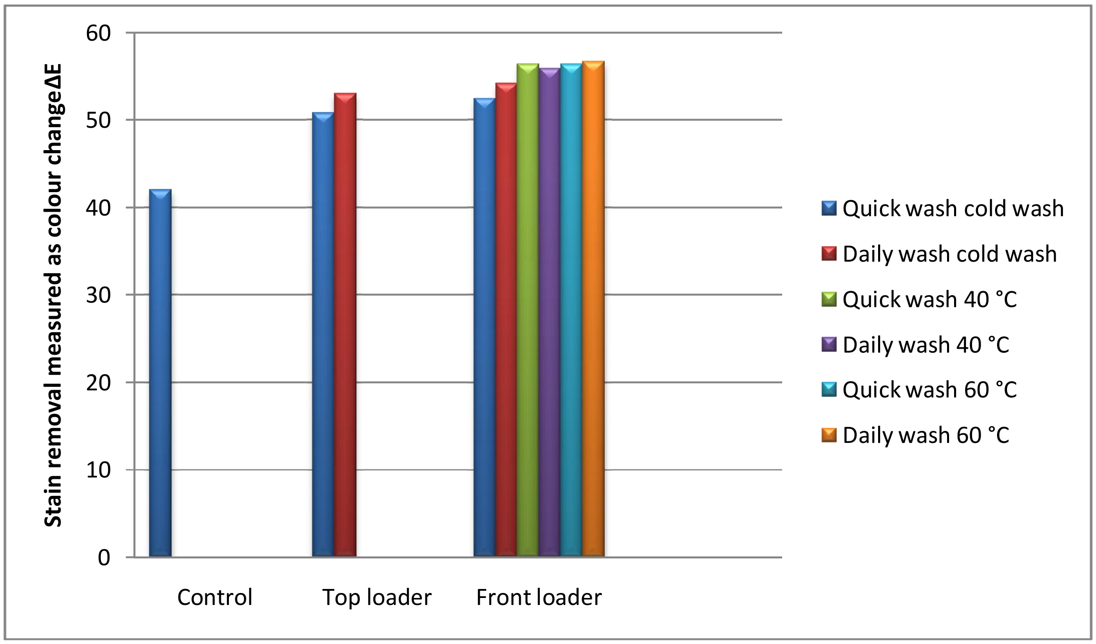

Figure 20: Blood/milk/ink stain removal in the top loader cold wash and the front loader at cold wash, 40 °C and 60 °C.

Table 24: Anova of how blood/milk/ink stain was removed at cold wash in the front loader and top loader.

	Std. deviation	Mean square	frequency	P-value
Quick wash	2	71.200	95.814	.000
Daily wash	2	24.701	31.962	.000

Table 24 above show that there was a significant statistical difference in colour on the removal of blood/milk/ink stain as the p-value was less than <0.05 in both the quick and daily wash programs of the top and front loader washing machines.

Table 25: Post hoc test comparing blood/milk/ink stain colour difference at cold wash, 40 °C and 60 °C in the front loader washing machine.

	Water temp.	Water temp.	Mean difference	Std. error	P-value
Quick wash	Cold wash	40 °C	-3.89333*	.35192	.000
		60 °C	-3.90000*	.31477	.000
	40 °C	Cold wash	3.89333*	.35192	.000
		60 °C	-.00667	.35192	1.000
	60 °C	Cold wash	3.90000*	.31477	.000
		40 °C	.00667	.35192	1.000
Daily wash	Cold wash	40 °C	-1.70667*	.32100	.000
		60 °C	-2.51333*	.32100	.000
	40 °C	Cold wash	1.70667*	.32100	.000
		60 °C	-.80667*	.32100	.041
	60 °C	Cold wash	2.51333*	.32100	.000
		40 °C	.80667*	.32100	.041

According to table 25, at quick wash program there was no significant difference in colour change between temperatures 40 °C and 60 °C as the p-value was 1.000.

4.5.4 Blood stain

Blood stain is a protein stain and tends to be difficult to remove. The results show that, blood stain was cleaned well in both machines but it washed better in the front loader at 40 °C and 60 °C wash temperatures. At 40 °C, blood was removed to a colour difference of 82.1 æE in the daily was and 83.0 æE when washed at 60 °C. According to literature, blood cleans better at lower temperature as at high temperatures the protein will coagulate making the stain to be fixed on to the fabric (Jo Dedic 1998:3). The results in this project were opposite to what the literature states as the blood stain was cleaned better at 40 °C and 60 °C.

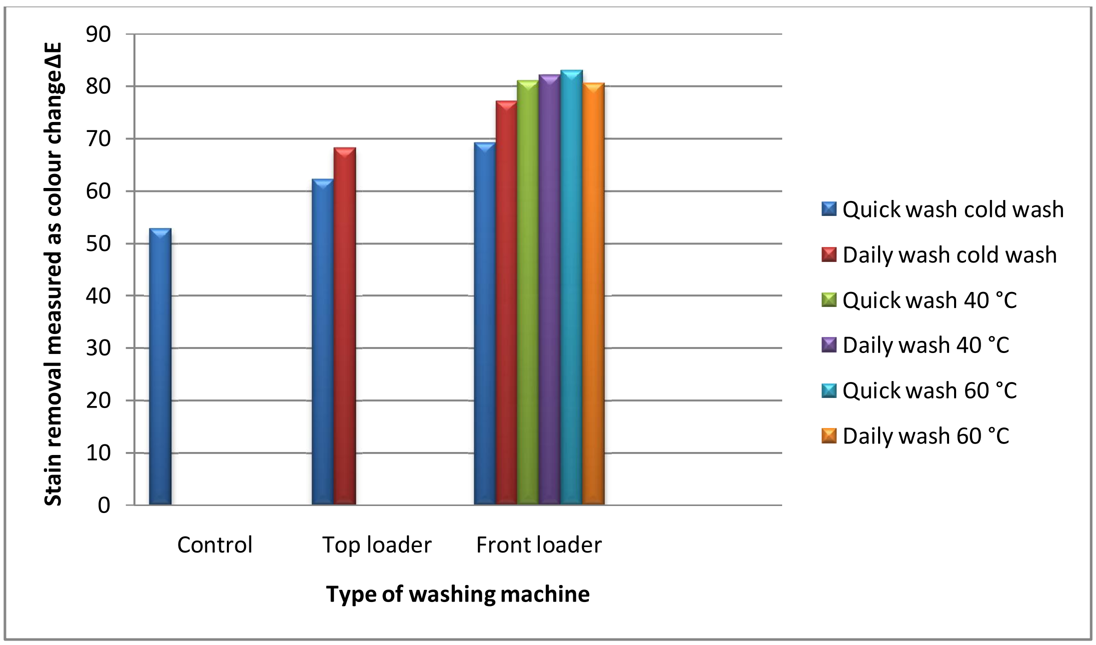

Figure 21: Blood stain removal in the top loader cold wash and the front loader at cold wash, 40 °C and 60 °C.

Table 26: Anova of how blood stain was removed at cold wash in the front loader and top loader.

	Std. deviation	Mean square	frequency	P-value
Quick wash	2	804.065	202.324	.000
Daily wash	2	95.596	28.769	.000

Table 26 above show that there was a significant statistical difference in colour in both the quick and daily wash programs of the top and front loader washing machines as the p-value was less than <0.05.

Table 27: Post hoc test comparing blood stain colour difference at cold wash, 40 °C and 60 °C in the front loader washing machine.

	Water temp.	Water temp.	Mean difference	Std. error	P-value
Quick wash	Cold wash	40 °C	-11.79667*	.81385	.000
		60 °C	-13.80000*	.72793	.000
	40 °C	Cold wash	11.79667*	.81385	.000
		60 °C	-2.00333*	.81385	.048
	60 °C	Cold wash	13.80000*	.72793	.000
		40 °C	2.00333*	.81385	.048
Daily wash	Cold wash	40 °C	-4.92667*	.66562	.000
		60 °C	-3.42000*	.66562	.000
	40 °C	Cold wash	4.92667*	.66562	.000
		60 °C	1.50667	.66562	.072
	60 °C	Cold wash	3.42000*	.66562	.000
		40 °C	-1.50667	.66562	.072

According to table 27, there was no significant statistical difference in colour between wash temperatures 40 °C and 60 °C in the daily wash program as the p-value in both were greater than 0.05. Whilst between other temperature combinations there were a significant colour change as the p-value was <0.05.

4.5.5 Egg yolk stain

The results in figure 22 below show that, egg yolk stain was not well removed when compared to the unwashed stain. This result was expected as the egg yolk stain is a protein stain developed to test for proteolytic enzyme activity. Figure 22 show that the stain was cleaned at the same level when washed in cold water in the top loader and front loader in the quick and daily wash programs. The stain removed slightly better in the front loader in the quick wash program at temperatures 40 °C and 60 °C. Even though egg yolk is a protein, it contains lots of fat hence it cleaned better at higher temperatures than in cold water. The detergent did not contain proteolytic enzyme, thus no better result was expected.

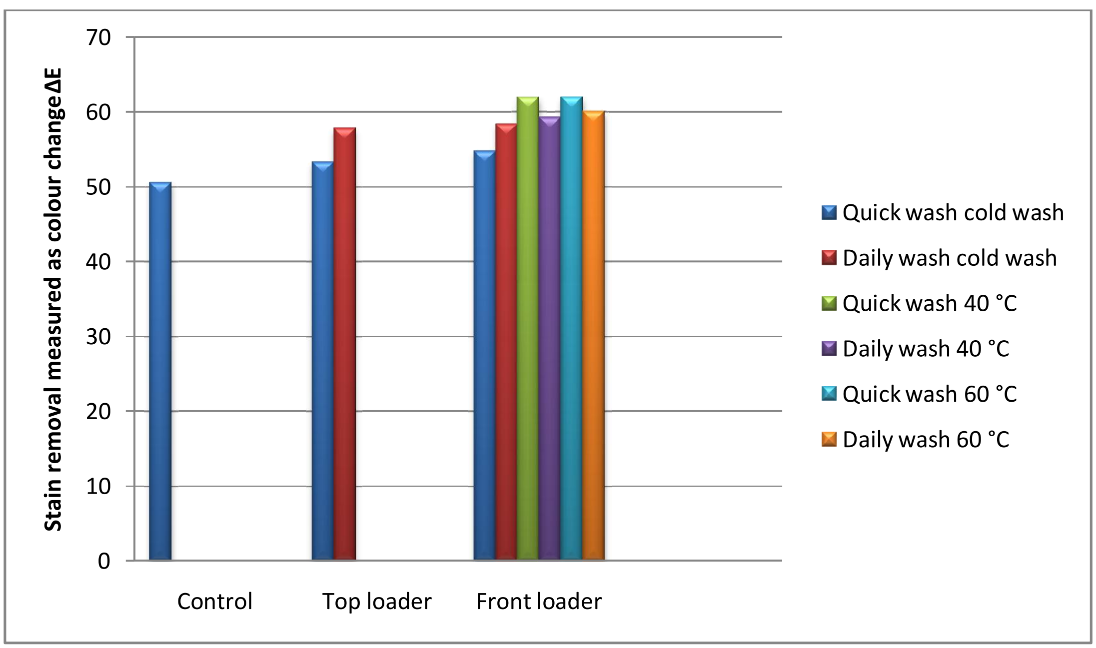

Figure 22: Egg yolk stain removal in the top loader cold wash and the front loader at cold wash 40 °C and 60 °C.

Table 28: Anova of how egg yolk stain was removed at cold wash in the front loader and top loader.

	Std. deviation	Mean square	frequency	P-value
Quick wash	2	244.264	41.131	.000
Daily wash	2	10926	5.458	.008

Table 28 above show that there was a significant statistical difference in colour on the removal of egg yolk stain as the p-value was less than <0.05 in the quick wash program and in the daily wash.

Table 29: Post hoc test comparing egg yolk stain colour difference at cold wash, 40 °C and 60 °C in the front loader washing machine.

	Water temp.	Water temp.	Mean difference	Std. error	P-value
Quick wash	Cold wash	40 °C	-7.23667*	.99488	.000
		60 °C	-7.20667*	.88984	.000
	40 °C	Cold wash	7.23667*	.99488	.000
		60 °C	.03000	.99488	.999
	60 °C	Cold wash	7.20667*	.88984	.000
		40 °C	-.03000	.99488	.999
Daily wash	Cold wash	40 °C	-.88000	.51662	.216
		60 °C	-1.70667*	.51662	.005
	40 °C	Cold wash	.88000	.51662	.216
		60 °C	-.82667	.51662	.257
	60 °C	Cold wash	1.70667*	.51662	.005
		40 °C	.82667	.51662	.257

According to table 29, in the quick wash program there was no significant difference in colour change between wash temperatures 40 °C and 60 °C as the p-value was 0.999. In the daily wash there was a significant difference in colour change between temperatures cold wash and 60 °C only while for the remaining temperatures there was no significant colour difference as the p-value was greater than 0.05.

4.5.6 Oatmeal/Chocolate stain

The results indicate that, oatmeal/chocolate stain was cleaned to the same extent by both machines. However fig. 23 show that the stain was cleaned best in the daily wash programs of both washing machines at cold wash in the top loader and front loader. The stain was least cleaned in the top loader quick wash program at cold wash water temperature, followed by the quick wash of the front loader at cold wash. It is clear from the results that the wash temperature did not matter much.

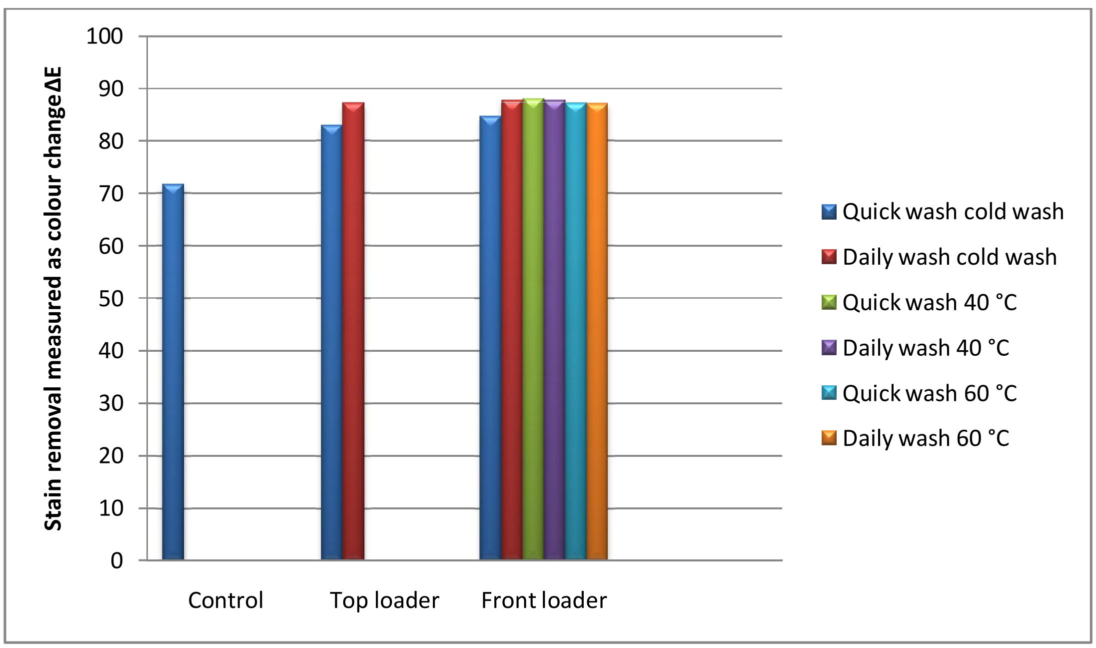

Figure 23: Oat meal/chocolate stain removal in the top loader cold wash and the front loader at cold wash, 40 °C and 60 °C.

Table 30: Anova of how oatmeal/chocolate stain was removed at cold wash in the front loader and top loader.

	Std. deviation	Mean square	frequency	P-value
Quick wash	2	42.039	96.956	.000
Daily wash	2	.939	4.669	.015

Table 30 above show that there was a significant statistical difference in colour on the removal of oatmeal/chocolate stain as the p-value was less than <0.05 in the quick wash program and the daily programs.

Table 31: Post hoc test comparing oatmeal/chocolate stain colour difference at cold wash, 40 °C and 60 °C wash temperatures in the front loader washing machine.

	Water temp.	Water temp.	Mean difference	Std. error	P-value
Quick wash	Cold wash	40 °C	-3.43333*	.26882	.000
		60 °C	-2.56667*	.24044	.000
	40 °C	Cold wash	3.43333*	.26882	.000
		60 °C	.86667*	.26882	.007
	60 °C	Cold wash	2.56667*	.24044	.000
		40 °C	-.86667*	.26882	.007
Daily wash	Cold wash	40 °C	.00000	.16374	1.000
		60 °C	.43333*	.16374	.030
	40 °C	Cold wash	.00000	.16374	1.000
		60 °C	.43333*	.16374	.030
	60 °C	Cold wash	-.43333*	.16374	.030
		40 °C	-.43333*	.16374	.030

According to table 31, there was a significant statistical difference in colour of the oatmeal/chocolate stain in the quick wash program between wash temperatures cold wash and 40 °C, cold wash and 60 °C, 40 °C and 60 °C as the p-values were <0.05. There was no significant difference between cold wash and 40 °C for the daily wash program.

4.5.7 Locust bean gum stain

The results on the removal of locust bean gum stain show that, the stain was cleaned well by both washing machines; however the front loader removed the stain much better than the top loader even at cold wash. The stain removal improved directly with increase in temperature. The daily wash program was more efficient in removal of the stain at every temperature. The best wash result was obtained with a colour difference of 74.6 æE with the daily wash program in the front loader machine at 60 °C. According to literature, locust bean gum is partially soluble in water at ambient temperature and soluble in hot water (Yoko 2008:1), hence it cleaned better at 60 °C and when laundered for a longer time.

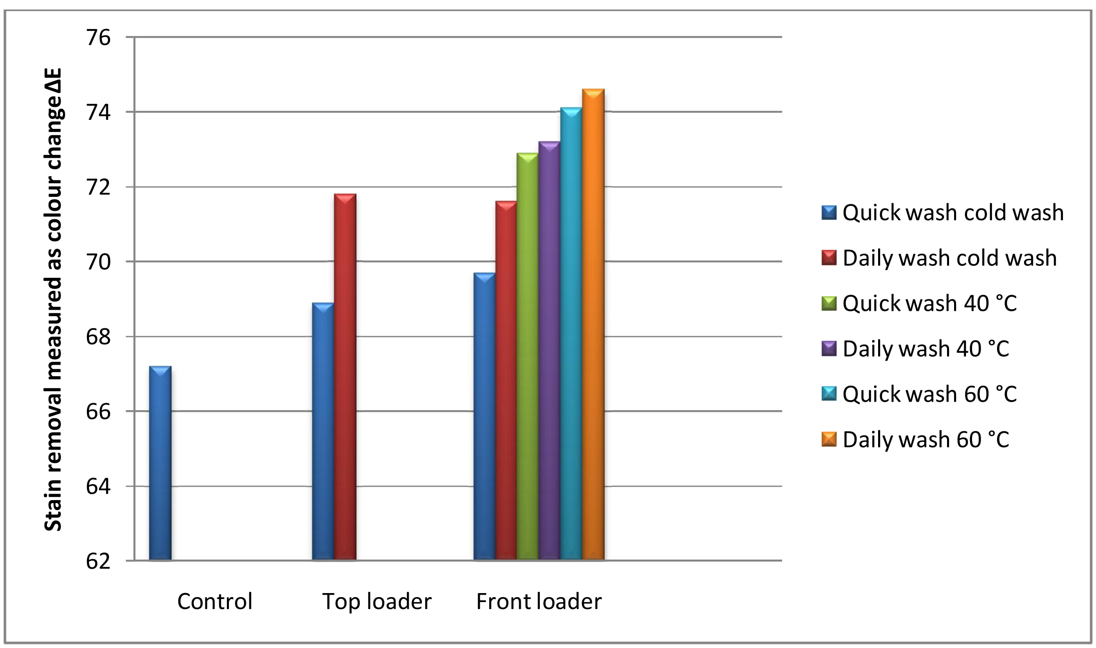

Figure 24: Locust bean gum stain removal in the top loader cold wash and the front loader at cold wash, 40 °C and 60 °C.

Table 32: Anova of how locust bean gum stain was removed at cold wash in the front loader and top loader.

	Std. deviation	Mean square	frequency	P-value
Quick wash	2	79.191	220.444	.000
Daily wash	2	35.654	130.427	.000

Table 32 above show that there was a significant statistical difference in colour on the removal of locust bean gum stain as the p-value was less than <0.05 in both quick wash and daily wash programs.

Table 33: Post hoc test comparing locust bean gum stain colour difference at cold wash, 40 °C and 60 °C in the front loader washing machine.

	Water temp.	Water temp.	Mean difference	Std. error	P-value
Quick wash	Cold wash	40 °C	-3.26333*	.24469	.000
		60 °C	-4.48000*	.21886	.000
	40 °C	Cold wash	3.26333*	.24469	.000
		60 °C	-1.21667*	.24469	.000
	60 °C	Cold wash	4.48000*	.21886	.000
		40 °C	1.21667*	.24469	.000
Daily wash	Cold wash	40 °C	-1.66667*	.19092	.000
		60 °C	-3.08000*	.19092	.000
	40 °C	Cold wash	1.66667*	.19092	.000
		60 °C	-1.41333*	.19092	.000
	60 °C	Cold wash	3.08000*	.19092	.000
		40 °C	1.41333*	.19092	.000

According to table 33, locust bean gum stain removal at one temperature differs significantly from every other temperature. In all the wash temperatures there has been a significant statistical difference in colour as the p-value was <0.05.

4.6 Particulates stains

4.6.1 Corn starch (coloured) stain

The results are interesting as the corn starch stain gets more intense rather than getting cleaned. Fig. 25 below shows that, the higher the temperature the more the stain was getting fixed. The unwashed sample gave a colour difference of 91.1 qE. Washing in cold water (cold wash) in the front loader quick wash gave a colour difference of 88.3 æE, washed at 40 °C lowers the colour difference lowered to 87.4 æE and the lowest colour difference of 86.8 æE was reached with temperatures 60 °C with the daily wash cycle. The colour pigment probably gets intensified with increase of temperature and/or shrinkage of the sample may cause the colour to seem intensified.

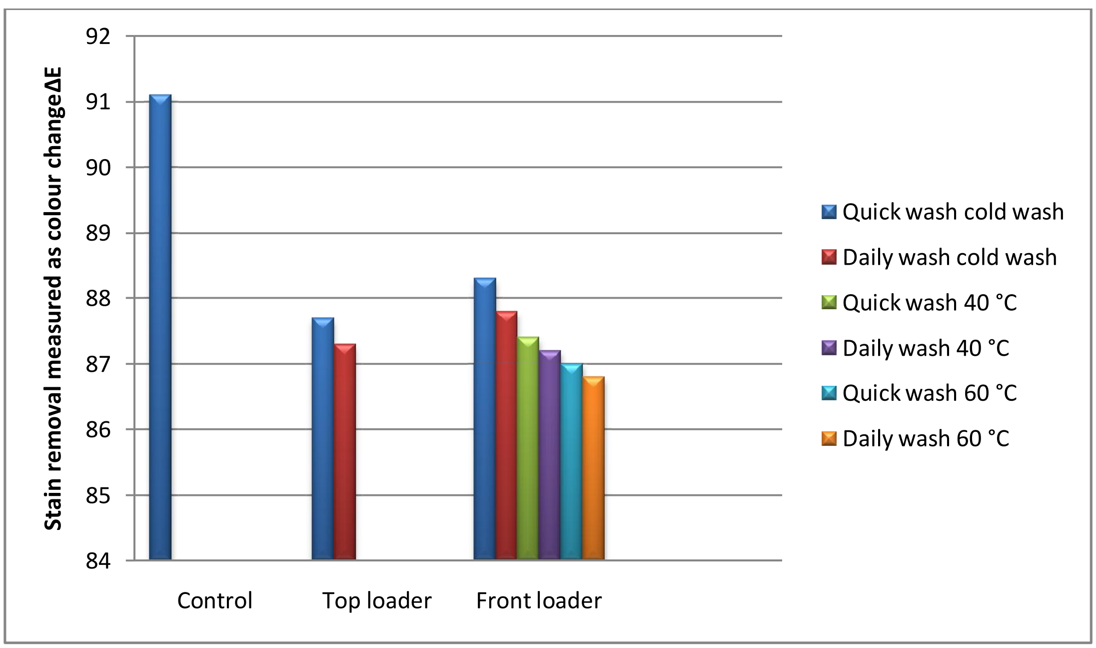

Figure 25: Corn starch stain removal in the top loader cold wash and front loader at cold wash, 40 °C and 60 °C.

Table 34: Anova of how corn starch stain was removed at cold wash in the front loader and top loader.

	Std. deviation	Mean square	frequency	P-value
Quick wash	2	6.347	40.556	.000
Daily wash	2	3.803	24.373	.000

Table 34 above show that there was a significant statistical difference in colour as the p-value was less than <0.05 in both quick and daily wash programs.

Table 35: Post hoc test comparing corn starch stain colour difference at cold wash, 40 °C and 60 °C in the front loader washing machine.

	Water temp.	Water temp.	Mean difference	Std. error	P-value
Quick wash	Cold wash	40 °C	.90333*	.16150	.000
		60 °C	1.27333*	.14445	.000
	40 °C	Cold wash	-.90333*	.16150	.000
		60 °C	.37000	.16150	.070
	60 °C	Cold wash	-1.27333*	.14445	.000
		40 °C	-.37000	.16150	.070
Daily wash	Cold wash	40 °C	.64000*	.14424	.000
		60 °C	.99333*	.14424	.000
	40 °C	Cold wash	-.64000*	.14424	.000
		60 °C	.35333*	.14424	.048
	60 °C	Cold wash	-.99333*	.14424	.000
		40 °C	-.35333*	.14424	.048

According to table 35, there was no significant statistical difference in colour between temperatures 40 °C and 60 °C as the p-value was greater than 0.05 in quick wash program. The other wash temperatures show significant difference from each other as the p-values were <0.05 in both the quick and daily wash programs.

4.6.2 Rice starch (coloured) stain

The results in figure 26 are similar to those in figure 25 as they are both starch, and as mentioned above the starch when washed interact physically and chemically thus changing their state and it makes the removal of the soil difficult as the results in figure 20 shows. Rice starch was not removed during laundering by both washing machines, but the rate at which it was not removed differs per machine. According to the results the higher the temperature the more intense the colour of the stain, once again it seem that the stain get fixed.

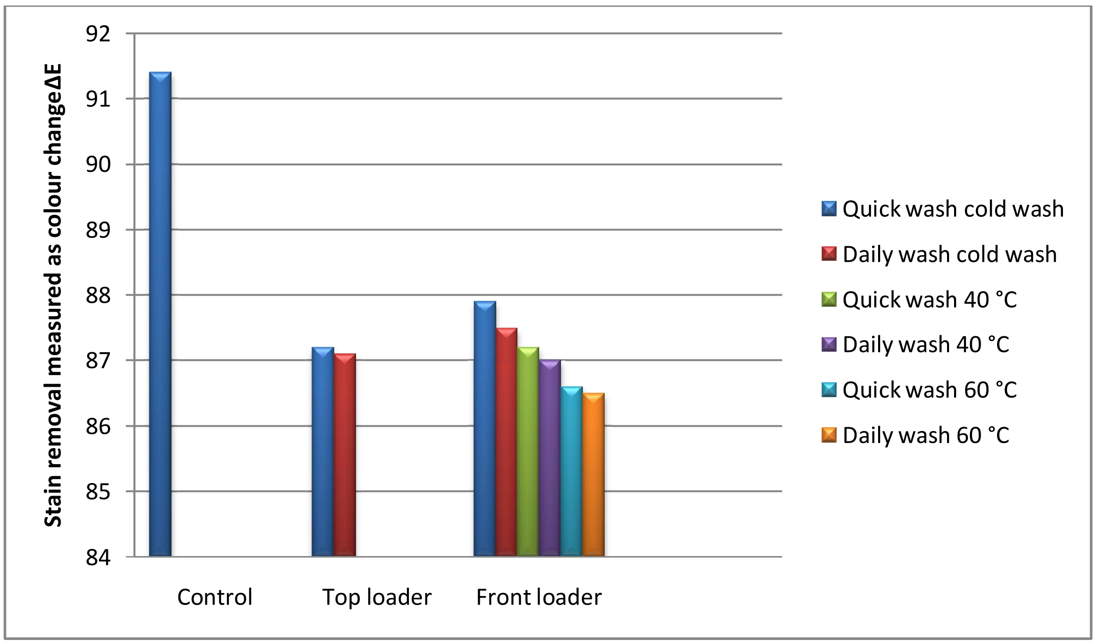

Figure 26: Rice starch stain removal in the top loader cold wash and the front loader at cold wash, 40 °C and 60 °C.

Table 36: Anova of how rice starch stain was removed at cold wash in the front loader and top loader.

	Std. deviation	Mean square	frequency	P-value
Quick wash	2	6.354	58.372	.000
Daily wash	2	3.942	16.984	.000

Table 36 above show that there was a significant statistical difference in colour on the rice starch stain as the p-value was less than <0.05 in both quick and daily wash programs.

Table 37: Post hoc test comparing rice starch stain colour difference at cold wash, 40 °C and 60 °C in the front loader washing machine.

	Water temp.	Water temp.	Mean difference	Std. error	P-value
Quick wash	Cold wash	40 °C	.71667*	.13469	.000
		60 °C	1.30000*	.12047	.000
	40 °C	Cold wash	-.71667*	.13469	.000
		60 °C	.58333*	.13469	.000
	60 °C	Cold wash	-1.30000*	.12047	.000
		40 °C	-.58333*	.13469	.000
Daily wash	Cold wash	40 °C	.42000	.17591	.055
		60 °C	1.02000*	.17591	.000
	40 °C	Cold wash	-.42000	.17591	.055
		60 °C	.60000*	.17591	.004
	60 °C	Cold wash	-1.02000*	.17591	.000
		40 °C	-.60000*	.17591	.004

According to table 37, there was a significant statistical difference in colour on the rice starch stain between all wash temperatures in the quick wash program as the p-value was <0.05. As for the daily wash program, there was no significant difference in the colour between temperatures cold wash and 40 °C as the p-value was greater than 0.05.

4.7 Bleachable stains

4.7.1 Coffee stain

Coffee stain is used to measure general detergency. The coffee stain as indicated in figure 27 was removed well in both washing machines. The best removals were obtained in the front loader at higher temperatures. At 40 °C the daily wash in the front loader machine removed the stain to a colour difference of 85.6 ∆E and even better results obtained when laundered at 60 °C. No colour difference in stain removal could be observed between the quick wash and daily wash at cold wash but there was a prominent difference between the quick wash and daily wash at 40 °C and 60 °C. According to literature coffee contains brown pigments, polymers and water soluble coloured substances (Kissa 1995:2) making the stain difficult to remove especially in cold water.

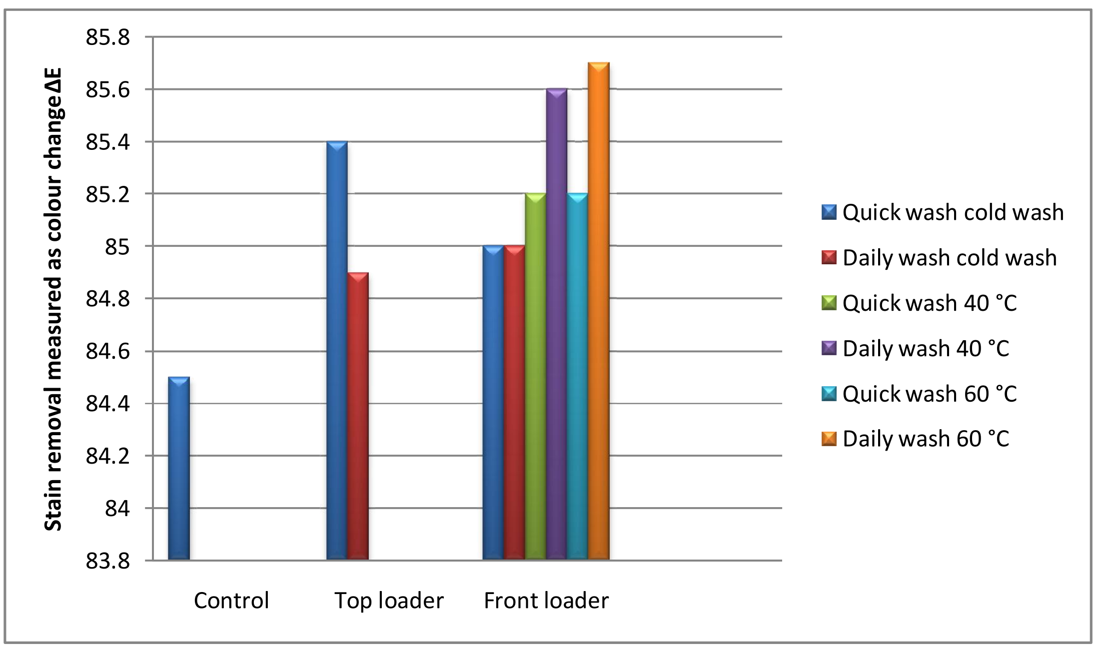

Figure 27: Coffee stain removal in the top loader cold wash and front loader at cold wash, 40 °C and 60 °C.

Table 38: Anova of how coffee stain was removed at cold wash in the front loader and top loader.

	Std. deviation	Mean square	frequency	P-value
Quick wash	2	.226	2.380	.107
Daily wash	2	1.723	12.223	.000

Table 38 above show that there was a significant statistical difference in colour on the removal of coffee stain as the p-value was less than <0.05 in the daily wash program while in the quick wash program there was no significant statistical difference in colour as p-value was greater than 0.05.

Table 39: Post hoc test comparing coffee stain colour difference at cold wash, 40 °C and 60 °C in the front loader washing machine.

	Water temp.	Water temp.	Mean difference	Std. error	P-value
Quick wash	Cold wash	40 °C	-.19333	.12587	.286
		60 °C	-.23333	.11258	.110
	40 °C	Cold wash	.19333	.12587	.286
		60 °C	-.04000	.12587	.946
	60 °C	Cold wash	.23333	.11258	.110
		40 °C	.04000	.12587	.946
Daily wash	Cold wash	40 °C	-.51333*	.13709	.002
		60 °C	-.64000*	.13709	.000
	40 °C	Cold wash	.51333*	.13709	.002
		60 °C	-.12667	.13709	.628
	60 °C	Cold wash	.64000*	.13709	.000
		40 °C	.12667	.13709	.628

According to table 39, there has been a significant statistical difference on the removal of the coffee stain in the daily wash program between wash temperatures cold wash and 40 °C, and cold wash and 60 °C but not between 40 °C and 60 °C.

4.7.2 Tea stain

Tea stains are difficult stains to remove as chromophores present in a hydrophobic matrix may impend the removal of the stain (Johansson & Somasundaran 2007:65), and mere washing may not remove the stain that well and bleaches may be needed. The stain was not removed at all in the front loader quick wash at cold wash, the 75 æE colour difference of the stain was the same as for the control. It was also noted that the top loader in both its quick and daily wash removed the stain much better than the front loader. As temperatures increase, the tea stain removal improved in the front loader, at 40 °C daily a value of 75.7 æE in colour difference was reached the same value as when washed at 60 °C with the quick wash, and slightly better in the daily program when the colour difference reached 75.8 æE. The addition of different flavours, colourings and plant elements has made the composition of teas more complex, and tea stain removal has become more difficult through these (Corina 2011:1).

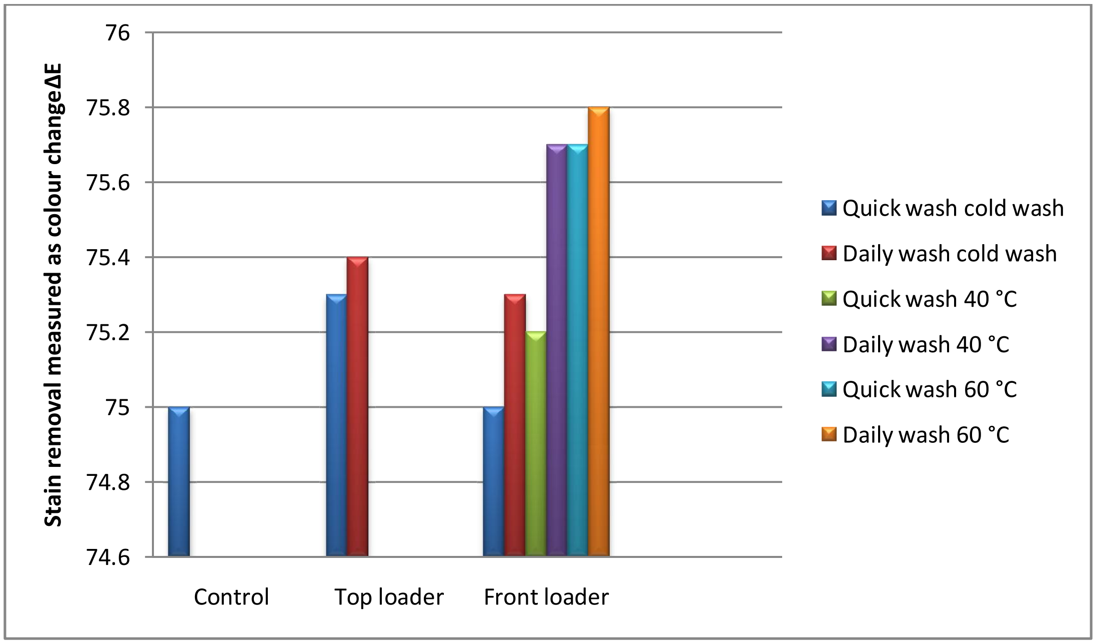

Figure 28: Tea stain removal in the top loader cold wash and front loader at cold wash, 40 °C and 60 °C.

Table 40: Anova of how tea stain was removed at cold wash in the front loader and top loader.

	Std. deviation	Mean square	frequency	P-value
Quick wash	2	2.062	8.797	.001
Daily wash	2	1.112	18.652	.000

Table 40 above show that there was a significant statistical difference on the removal of tea stain as the p-value was less than <0.05 in both wash programs.

Table 41: Post hoc test comparing tea stain colour difference at cold wash, 40 °C and 60 °C in the front loader washing machine.

	Water temp.	Water temp.	Mean difference	Std. error	P-value
Quick wash	Cold wash	40 °C	-.32333	.19764	.244
		60 °C	-.74000*	.17677	.000
	40 °C	Cold wash	.32333	.19764	.244
		60 °C	-.41667	.19764	.102
	60 °C	Cold wash	.74000*	.17677	.000
		40 °C	.41667	.19764	.102
Daily wash	Cold wash	40 °C	-.40000*	.08916	.000
		60 °C	-.52000*	.08916	.000
	40 °C	Cold wash	.40000*	.08916	.000
		60 °C	-.12000	.08916	.378
	60 °C	Cold wash	.52000*	.08916	.000
		40 °C	.12000	.08916	.378

According to table 41, there was a significant statistical difference on the removal of tea stain between the following temperatures; cold wash and 60 °C in the quick wash program, and in the daily wash program cold wash and 40 °C and cold wash and 60 °C as the p-value was <0.05. As for the other temperature comparisons in both quick and daily wash programs there was no significant statistical difference in colour as the p-value was greater than 0.05.

4.7.3 Blackcurrant stain

As figure 29 indicates blackcurrant stain was removed by both washing machines at almost the same rate. The figure furthermore shows that blackcurrant stain was cleaned at the same level in the daily wash program by both the top and front loader at cold wash. It was also noted that in the front loader all the wash temperatures removed the stain at the same rate. The stain was though least removed in the top loader quick wash. Literature states that, anthocyanins are natural colour pigment in blackcurrant and are soluble in water (Deven*et al.*2010:1055) hence blackcurrant stain was removed in both washing machines at a similar rate.

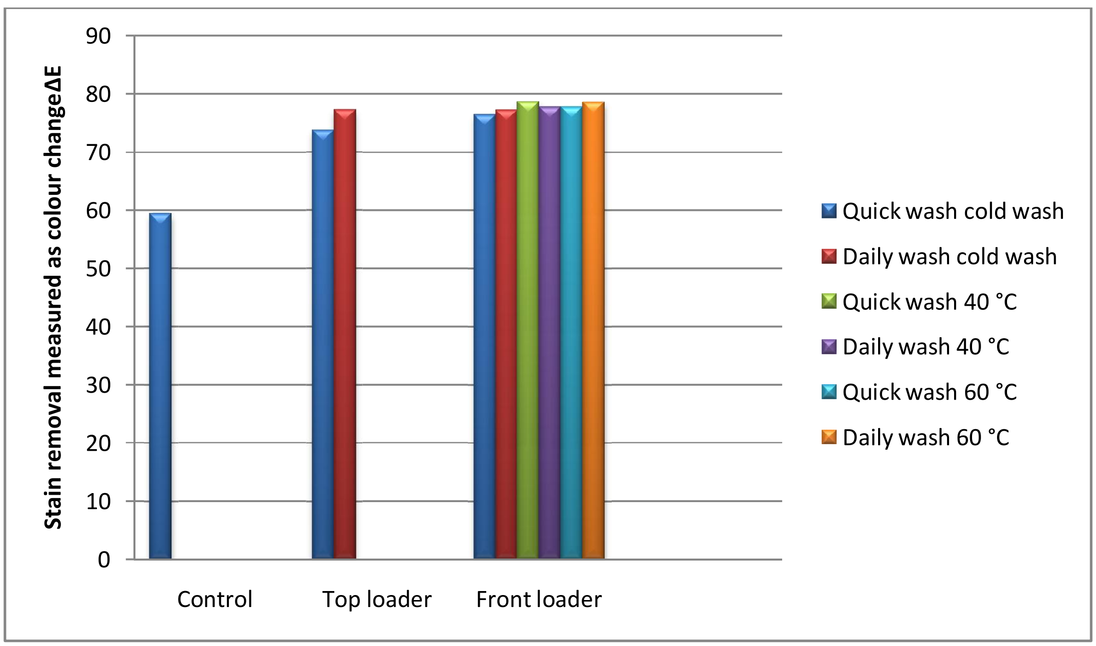

Figure 29: Blackcurrant stain removal in the top loader cold wash and the front loader at cold wash, 40 °C and 60 °C.

Table 42: Anova of how blackcurrant stain was removed at cold wash in the front loader and top loader.

	Std. deviation	Mean square	frequency	P-value
Quick wash	2	15.813	65.672	.000
Daily wash	2	7.438	18.377	.000

Table 42 above show that there was a significant statistical difference in colouras the p-value was less than <0.05.

Table 43: Post hoc test comparing blackcurrant stain colour difference at cold wash, 40 °C and 60 °C in the front loader washing machine.

	Water temp.	Water temp.	Mean difference	Std. error	P-value
Quick wash	Cold wash	40 °C	-2.25333*	.20033	.000
		60 °C	-1.25333*	.17918	.000
	40 °C	Cold wash	2.25333*	.20033	.000
		60 °C	1.00000*	.20033	.000
	60 °C	Cold wash	1.25333*	.17918	.000
		40 °C	-1.00000*	.20033	.000
Daily wash	Cold wash	40 °C	-.48000	.23231	.109
		60 °C	-1.38667*	.23231	.000
	40 °C	Cold wash	.48000	.23231	.109
		60 °C	-.90667*	.23231	.001
	60 °C	Cold wash	1.38667*	.23231	.000
		40 °C	.90667*	.23231	.001

According to table 43, there was no significant statistical difference on the removal of blackcurrant stain in daily wash program between wash temperatures cold wash and 40 °C as the p-value was greater than 0.05, as for other temperature comparisons there were a significant statistical difference in stain removal as the p-value was <0.05.

4.7.4 Red wine stain

Figure 30 below show that, red wine stain was removed by both machines at a similar low rate. The wash temperature and the kind of wash cycle did not influence the stain removal. According to literature, anthocyanins are the natural pigment for wine (Huang *et al.* 2009:819), wine is a milieu of chemicals that can interact (Rallof 1994:10) and the tannins found in wine contribute to the colour stability and make a wine stain difficult to remove.

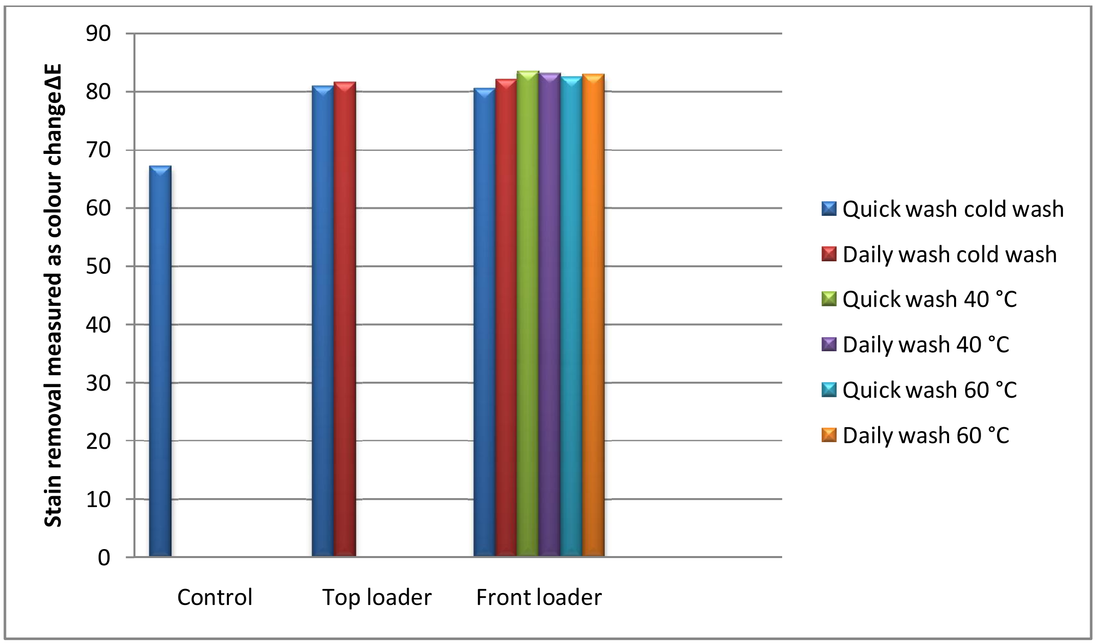

Figure 30: Red wine stain removal in the top loader cold wash and the front loader at cold wash, 40 °C and 60 °C.

Table 44: Anova of how red wine stain was removed at cold wash in the front loader and top loader.

	Std. deviation	Mean square	frequency	P-value
Quick wash	2	30.000	195.285	.000
Daily wash	2	4.568	39.347	.000

Table 44 above show that there was a significant statistical difference in colour on the removal of red wine as the p-value was less than <0.05.

Table 45: Post hoc test comparing red wine stain colour difference at cold wash, 40 °C and 60 °C in the front loader washing machine.

	Water temp.	Water temp.	Mean difference	Std. error	P-value
Quick wash	Cold wash	40 °C	-3.00000*	.16001	.000
		60 °C	-2.00000*	.14312	.000
	40 °C	Cold wash	3.00000*	.16001	.000
		60 °C	1.00000*	.16001	.000
	60 °C	Cold wash	2.00000*	.14312	.000
		40 °C	-1.00000*	.16001	.000
Daily wash	Cold wash	40 °C	-1.04000*	.12442	.000
		60 °C	-.84000*	.12442	.000
	40 °C	Cold wash	1.04000*	.12442	.000
		60 °C	.20000	.12442	.254
	60 °C	Cold wash	.84000*	.12442	.000
		40 °C	-.20000	.12442	.254

According to table 45, in the quick wash program all temperature comparisons showed a significant statistical difference in colour as the p-value was <0.05. While in the daily program, the only temperatures which did not show a significant statistical difference in colour were temperature comparison between 40 °C and 60 °C as their p-value was >0.05.

4.8 White cotton (redeposition)

The white cotton had no stain on it and it was used to check the level of redeposition in the different washes. As figure 31 indicates laundering with the daily wash program at cold wash in the front loader produced a sample whiter than the white cotton, thus no redeposition, all the other show some redeposition. It is not possible to draw a clear conclusion from this results, it may mean that no redeposition took place as the stain removal at that temperature was low. Laundering with daily cycle at 60 °C did not show redeposition either and that was the temperature and cycle that gave the best stain removal throughout the project.

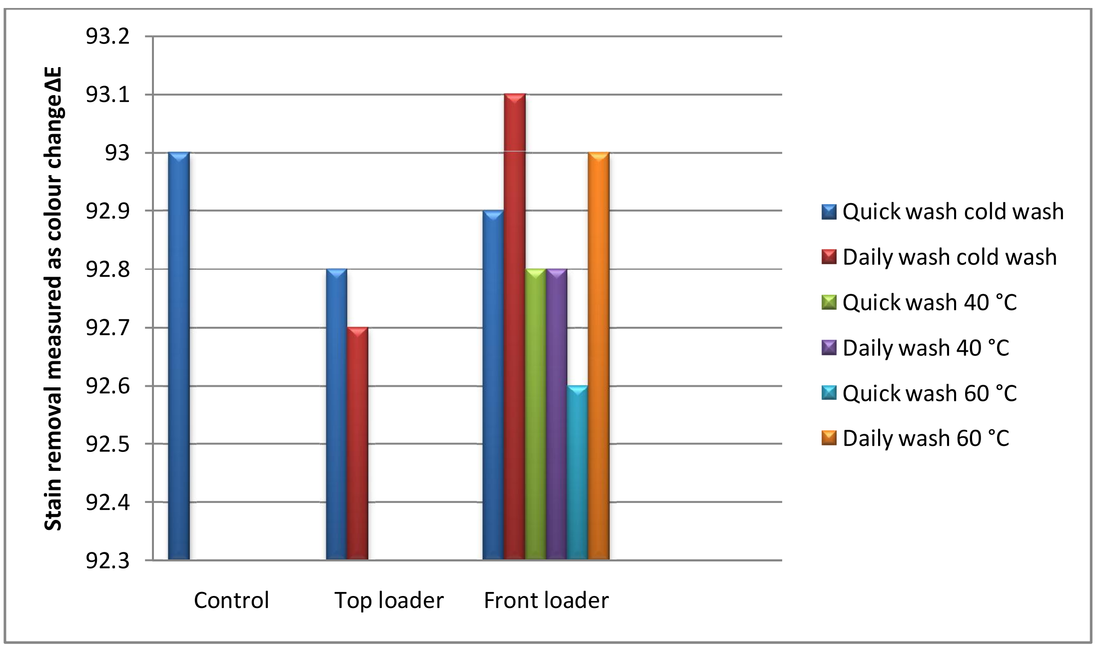

Figure 31: Redeposition on white cotton in the top loader cold wash and at cold wash, 40 °C and 60 °C in the front loader washing machine.

Table 46: Anova of stain redeposition on white cotton at cold wash in the front loader and top loader.

	Std. deviation	Mean square	frequency	P-value
Quick wash	2	.065	.472	.627
Daily wash	2	.403	3.628	.035

Table 46 above show that there was no significant statistical difference in the redeposition in the quick wash program as the p-value was larger than 0.627. There was a significant statistical difference between the daily wash of the two machines.

Table 47: Post hoc test comparing redeposition of soil at cold wash, 40 °C and 60 °C in the front loader washing machine.

	Water temp.	Water temp.	Mean difference	Std. error	P-value
Quick wash	Cold wash	40 °C	.09333	.15107	.811
		60 °C	-.05333	.13512	.918
	40 °C	Cold wash	-.09333	.15107	.811
		60 °C	-.14667	.15107	.600
	60 °C	Cold wash	.05333	.13512	.918
		40 °C	.14667	.15107	.600
Daily wash	Cold wash	40 °C	.32667*	.12168	.027
		60 °C	.14000	.12168	.489
	40 °C	Cold wash	-.32667*	.12168	.027
		60 °C	-.18667	.12168	.286
	60 °C	Cold wash	-.14000	.12168	.489
		40 °C	.18667	.12168	.286

According to table 47, in both the quick and daily wash programs there has been no significant statistical difference in re-deposition of soil in all the wash temperatures as the p-valueôs were all >0.05 except for cold wash and 40 °C in the daily wash cycle where a significant statistical difference occurred.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The aim of this study was to determine the water consumption, energy consumption and soil removal efficiency of a front and a top loader washing machine from the same capacity and the same manufacturer. This was achieved by evaluating the performance of the washing machines when laundering. Electricity was measured in watt-hour using an electricity measuring instrument. Water was measured in litre and the rate at which soil was removed from the soiled fabric was calculated in æE(colour difference) from the L*a*b* values measured with a colorimeter.

From the results obtained, conclusions were drawn based on the hypotheses and objectives relating to the performance of both washing machines.

According to hypothesis 1 the top loader would use more water as the front loader washing machine. The results have shown that, the top loading washing machine used more water compared to the front loading machine. In fact, the front loader quick wash program used 57ă and the daily wash program used 60ă While with the top loader the quick wash program used 114ă and the daily wash program used 170ă of water. The top loader daily wash used almost 3 times the amount of water used in a single wash by the front loader. Hypothesis 1 is therefore accepted.

Hypothesis 2 stated that, the top loader washing machine would use less energy than the front loader. Both washing machines were connected to the cold water tap. As explained before the front loader has a heating element which heats water to various temperatures, whilst the top loader has to be connected to a hot water tap for it to launder using warm or hot water option. The results have indicated thattop loader washing machine used less energy as compared to the front loader. Therefore hypothesis 2 has been proven to be true that the top loader uses less energy.

According to hypothesis 3 laundering at high temperatures will use more electricity. As the front loader had a number of wash temperatures, temperatures 30 °C, 40 °C and 60 °C were used to launder the samples and recorded the amount of energy used in both the quick and daily wash programs. It was noted that as the wash cycle took a longer time and temperatures increased so was the amount of electricity used. The results indicated that; a quick wash in the front loader at 30 °C used 862 Wh electricity, a daily wash at 30 °C used 1616 Wh electricity, a quick wash at 40 °C used 1555 Wh electricity, a daily wash at 40 °C used 2049 Wh electricity, a quick wash at 60 °C used 2314 Wh electricity and lastly a daily wash at 60 °C used 2400 Wh electricity. This clearly show that the amount of electricity increased as the temperature rose. Therefore hypothesis 3 is proven true that laundering at high temperatures uses more electricity.

Hypothesis 4 states that the front loader washing machine would be more efficient in soil and stain removal than the top loader washing machine. According to the results, most soils and stains were better removed in the front loader than those laundered in the top loader. The stains and soils that removed better in the front loader were: red wine, blackcurrant, tea, coffee, rice starch, corn starch, dressing, locust bean gum, oatmeal/chocolate, egg yolk/pigment, blood, blood/milk/ink, grass, cocoa, pigment/oil/milk, olive oil/soot, sebum bey, make-up, lipstick and aged oil stained samples. The Anova indicated that all these stains and soils cleaned better in the front loader. Therefore hypothesis 4 was accepted that laundering with a front loader removes soils and stains better.

According to hypothesis 5 the quick wash program will use less energy than the daily wash program. The results have shown that the quick program uses less energy than the daily program as it was recorded as follows; the quick wash at 30 °C used 862 Wh while the daily wash at 30 °C used 1616 Wh, the quick wash at 40 °C used 1555 Wh, while the daily wash at 40 °C used 2049 Wh and the quick wash at 60 °C used 2314 Wh while the daily wash at 60 °C used 2400 Wh. It was evident that the difference in energy used was more prominent at 30 °C than at 60 °C. The quick wash program used less energy as it uses less time to wash. The quick wash program at 30 °C used 28 minutes, the daily wash at the same temperature used 65 minutes, quick wash 40 °C use 59 minutes, daily at the same temperature used 65 minutes, quick wash at 60 °C took 59 minutes and daily wash took 65 minutes. Comparing the time and amount of energy used it is found that the longer the wash time the more energy used, the difference in time used to complete the program became less as the temperature rose. Hypothesis 5 is accepted that the quick wash will use less energy than the daily wash program.

Hypothesis 6 stated that, the quick wash program will use less water than the daily program. The results have indicated that the quick wash program for both washing machines used less water than the daily wash program. It was recorded that; the front loader quick wash used 57ǎ and the daily used 60ǎ which is almost the same amount of water, while with the top loader the quick wash program used 114ǎ and daily washes 170ǎ of water. There was a significant difference in the amount of water used in the top loader as opposed to the front loader. Therefore, hypothesis 6 has been partially accepted, the quick wash used less water than the daily wash program for the top loader washing machine but not for the front loader washing machine.

According to hypothesis 7 the quick wash program will remove less soil and stains from the fabric than the daily program. The results show that, the daily program removed the aged oil soil better than the quick wash. Lipstick, make up, sebum bey, olive oil/soot, pigment oil, dressing, cocoa, grass, blood/milk/ink, blood, egg yolk, oatmeal/chocolate, locust bean gum, coffee, tea, red wine and blackcurrant stains were removed better in the daily wash program than in the quick wash program. Therefore hypothesis 7 is accepted that the quick wash program removes less soil and stains from fabric than the daily program.

According to hypothesis 8 soil re-deposition will not take place during the quick or daily wash program of the top and front loader washing machines. The results indicate that there was no re-deposition in the front loader daily wash program at cold wash temperature as the sample was even whiter than the unwashed sample. As for other wash programs the results indicate that there was soil re-deposition. Therefore, hypothesis 8 has been partially accepted, soil re-deposition did not take place in the front loader daily wash at cold wash but took place for all other wash programs in both washing machines.

The top loader has shown that it uses less water than the front loader, the front loader uses more electricity than the top loader and the front loader cleans better than the top loader. A consumer will be faced with a difficult choice to either save water or electricity and if they value a better cleaning washing machine. They will select the front loader washing machine but knowing that they will use more energy.

5.2 Recommendations

It is recommended that full loads are used to restrict the number of loads washed and thereby saving water and energy. It is further recommended that more top and front loader washing machines be tested to determine whether the same results would be obtained with other brands.

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ABSTRACT

Water and energy are used in the domestic laundering processes for optimum soil and stain removal. Water and energy conservation are important issues in the quest for more

environment friendly household practices. Washing machines have been invented as household gadgets making laundry easier and faster. Common types of washing machine include top loaders, front loaders and twin tubs. Literature indicate that top loaders use less electricity but more water and front loaders use less water but more electricity. However efficient soil removal is the main concern of the consumer.

The purpose of the study was to determine water, energy and soil removal efficiency of a top loader and a front loader washing machine. A quantitative research strategy was used and controlled experiments were conducted in order to attain accurate data. An 8.0 kg capacity top loader and an 8.5 kg capacity front loader of the same manufacturer were purchased. The õdaily wash programö and the õquick wash programö of both machines were selected as wash programs for the project. Cold wash (water at room temperature) was used for the top loader and cold wash, 30 °C, 40 °C and 60 °C for the front loader. A 5kg load of 3 samples of C-09 cotton (soiled with pigment oil, purchased from CFT) and cotton filler cloths were used for each wash cycle and each cycle repeated three times. The efficiency of the machines and programs to remove stains were tested on the following stains: CS-103 red wine, CS-12 blackcurrant, CS-BC-03 tea, C-BC-02 coffee, CS-28 rice starch, CS-26 corn starch, CS-6 dressing, CS-73 locust bean gum, CS-54 oatmeal/chocolate, CS-38 egg yolk/pigment, CS-01 blood, C-05 blood/milk/ink, CS-08 grass, CS-02 cocoa, C-10 pigment/oil/milk, C-02 olive oil/soot, CS-32 sebum bey, CS-17 make-up and CS-216 lipstick. 60g Non phosphate ECE reference detergent without optical brightener was used. Redeposition of soil was determined on CN-11 white cotton.

The drained water was collected and measured in litres. The energy consumption was measured in watt-hour in every program. Soil removal was measured with a colorimeter in CIE L*a*b* colour scale (AATCC test method 61-2010) and an analysis of variance was used to aid in the interpretation of the data. The results of the study indicate that, the top loader used more water than the front loader. The daily wash used more water than the quick wash in both the top loader and front loader. The front loader used more energy than

the top loader at cold wash. More energy was used in the daily wash than quick wash of the front loader. It was also evident that the daily wash program in both machines was more efficient in soil and stain removal than the quick wash. At cold wash the daily wash was more efficient in soil and stain removal than the quick wash program but at 60 °C there was no difference in the rate of stain removal in both the quick and daily wash programs. The best soil and stain removal was observed at 60 °C in both the quick and daily programs. The top loader machine used more water, less energy and removed less soil and stain. It was also evident that, the front loader washing machine is more efficient in soil and stain removal and it uses less water but it uses more energy than the top loader machine.

Key words: energy consumption, water consumption, soil removal, stain removal, household washing machine and home laundering.

OPSOMMING

Water en energie word in die huishoudelikewasprosesgebruikomvuil en vlekketeverwyder. Water en energiebesparing is belangrikekwessies in die

strewenameeromgewingsvriendelikehuishoudelikepraktyke. Was masjiene is ontwikkel as toerustingomwasgoed was makliker en vinnigertemaak. Die algemenetipeswasmasjienevandag is: bo-laaiers, voor-laaiers en dubbelbaliewasmasjiene.Dieliteratuur dui aandatbo-laaiers minder energiegebruik, maar meer water en datvoor-laaiers minder water gebruik, maar meerenergie. Vir die verbruiker is vuiverwydering die belangriksteaspek.

Die doel van die studie was om die water -, energie - en vuilverwyderingdoeltreffendheid van die bo-laaier en die voor-laaierwasmasjientebepaal. 'nKwantitatiewenavorsingstrategie is gebruik en gekontroleerdeeksperimente is uitgevoeromakkurate data teverkry. 'n Bo-laaier met 8 kg kapasiteit en 'n 8.5 kg kapasiteitvoorlaaierwasmasjien van dieselfdehandelsmerk is aangekoopvir die eksprimente. Die "daagliksewasprogram" en die "vinnigewasprogram" is gekiesvir die projek.Koue was (kamertemperatuur) is gebruikvir die bo-laaier en 20°C, 30°C, 40°C en 60°C vir die voorlaaier. 'n Wasbondel van 5 kg gevormdeur 3x C-09 katoenmonsters (aangevuil met pigment olieaangekoop van CFT) en katoen-vullerstukke is gebruikvirelkesiklus, en elkesiklus is driemaalherhaal. Die doeltreffendheid van die masjiene en die programme omvuil en vlekketeverwyder is op die volgendevlekkegetoets: CS-103 rooiwyn, CS-28 rysstysel, CS-12 swartbessie, CS-BC-03 tee, C-BC-02 koffie, CS-26 mieliestysel, CS-6 sous, CS-73 kassia boon gom, CS-54 hawermout/sjokolade, CS-38 eiergeel/pigment, CS-01 bloed, CS-05 bloed/melk/ink, CS-08 gras, CS-02 kakao, C-10 pigment/olie/melk, C-02 olyfolie/roet, CS-32 sebum, CS-17 grimering, CS-216 lipstiffie. 60g Nie-fospfaat (ECE) standaard detergent sonderoptieseverhelderaar is gebruik. Herneerlegging van vuil is op CN-11 witkatoenwaargeneem.

Die afvoerwater is opgevang en in litergemeet. Die energieverbruik is virelke program in Watt-uurgemeet. Die vuilverwydering is met 'n Colorimeter in die CIE L*a*b* kleurskaalgemeetvolgens die AATCC 61-2010toetsmetode en 'n variansieanalise is gedoenom die interpretasie van die resultatetevergemaklik.

Die resultate van die studie het aangetoondat die bo-laaiermeer water gebruik as die voorlaaier. Die "daagliksewasprogram" het meer water gebruik as die "vinnige program" in beide die voor-laaier en bo-laaier. Die voor-laaier het meerenergiegebruik as die bo-laaier met koue water (20°C). Dit was ookduidelikdat die "daaglikse program" meerenergiegebruik het as die "vinnige program" in die voor-laaier. Die "daagliksewasprogram" was in beide die bo-laaier en die voor-laaiermeerdoeltreffend in vuilverwydering. By 20°C was die "daaglikse program" meerdoeltreffend in vuil- en vlekverwydering as die "vinnigewasprogram" , maar by 60°C was daarnie n' verskil in vuilverwydering en vlekverwyderingtussen die "daaglikse -" en "vinnigewasprogram" nie. Die bestevuilverwydering is in die "vinnige -" en die "daaglikse program" by 60°C in die voorlaaierwaargeneem.

Die bo-laaiergebruikmeer water, minder energie en verwyder minder vuil en vlekke. Dit was duidelikdat die voor-laaierwasmasjienmeerdoeltreffend was in vuil- en vlekverwydering en minder water gebruik, maar ditgebruikmeerenergie as die bo-laaier.

Sleutelwoorde: Energieverbruik, waterverbruik, vuilverwydering, huishoudelikewasmasjien, huishoudelikewasproses.

APPENDIX: A

CFT Standard Monitors

CFT SM-04 All Purpose Monitor

Multi Swatch Monitors are becoming more and more popular in the industry. Most of the times this will be a custom selected combination of testmaterials.

CFT also introduces the SM-04 All Purpose Monitor:

CS-103 Red Wine – BLEACH
CS-12 Blackcurrant – BLEACH
C-BC-03 Tea – BLEACH/TEMP
C-BC-02 Coffee – BLEACH
CN-11 White Cotton – REDEPOSITION
CS-28 Rice Starch – AMYLASE
CS-26 Corn Starch – AMYLASE
CS-6 Dressing – AMYLASE/MANANASE
CS-73 Locustbeangum – MANNANASE
CS-54 Oatmeal/Chocolate – CELLULASE
CS-38 Egg yolk/pigment – PROTEASE
CS-01 Blood – PROTEASE
C-05 Blood/milk/ink – PROTEASE
CS-08 Grass – STAIN REMOVAL
CS-02 Cocoa – STAIN REMOVAL/TEMP
C-10 Pigment/Oil/Milk – GENERAL
C-02 Olive Oil/Soot – PARTICLE/FATS
CS-32 Sebum Bey – FATS
CS-17 Make-up – PARTICLES
CS-216 Lipstick – PARTICLE/FATS

The configuration of the CFT SM-04 All Purpose Monitor is given below. Price is 10,- euro per monitor.

CFT-SM04 2009 - on PN-33

packed by: N003 Amount: 10 pcs Store at: 3-5ºC

C-S-103	C-S-12	C-BC-03	C-BC-02	CN-11 w3x
C-S-28	C-S-26	C-S-06	C-S-73	C-S-54
C-S-38	C-01	C-05	C-S-08	C-S-02
C-10	C-02	C-S-32	C-S-17	C-S-216

Produced by Center For Testmaterials BV. The Netherlands
E-mail: info@cftbv.nl - +31 10 460 39 55 - Website: www.cftbv.nl

MACH 5

CFT is developing a new technology to speed up measuring multi-swatch monitors and multi-stain monitors. This machine is called the Multi-Area Color-measurement Hardware: MACH 5

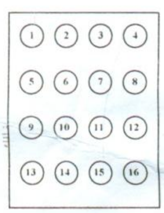
Measure dE, Reflection, LAB, XYZ etc. Up to 20 times as fast!

This device is especially suitable to measure these types of standard monitors, as well Multi-Swatch as Multi-Stain Monitors. All soils and stains can be measured in only one measurement. This will save you precious time in testing.

The Demo Version will be presented at our Center For Testmaterials booth.

STANDARD AND CUSTOM MULTISTAIN MONITORS

Due to the opportunities that the MACH 5 will give you for measuring Multi-Stain Monitors, CFT has also introduced the new A4 size CFT SM-08 Standard Multi-Stain Monitor on Knitted Cotton. This is available for only 12.50 euro/monitor. Next to this standard, a custom configuration is also possible.



CFT SM-08 Multi-Stain Monitor
on CN-42 Knitted Cotton
Ø = 2.5cm

1 = KC-H129 Make-up
2 = KC-H021 Lipstick
3 = KC-H026 Red Wine
4 = empty
5 = KC-H137 Tomato/Oil
6 = KC-H007 Blood
7 = KC-H009 Choc. Ice
8 = KC-H082 Sebum Bey
9 = KC-H028 Tea
10 = KC-H147 Jam
11 = KC-H039 Grass
12 = KC-H015 Frying Fat
13 = KC-H040 Baby Food
14 = KC-H115 Clay
15 = KC-H131 Butterfat
16 = KC-H013 DMO

Example of a Custom Multi-Stain
Monitor on CN-42 Knitted Cotton
Ø = 2.5cm

1 = Mascara
2 = Jam
3 = Strawberry
4 = Red Wine
5 = Shoe polish
6 = Brown sauce
7 = Egg yolk
8 = Fruit Juice
9 = Lipstick
10 = Curry
11 = Blood
12 = Coffee
13 = Make-up
14 = Clay
15 = Babyfood
16 = DMO

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Center For Testmaterials BV
Stoomloggerweg 11, 3133 KT Vlaardingen, the Netherlands ~ PO Box 120, 3130 AC Vlaardingen, the Netherlands
www.cftbv.nl ~ info@cftbv.nl